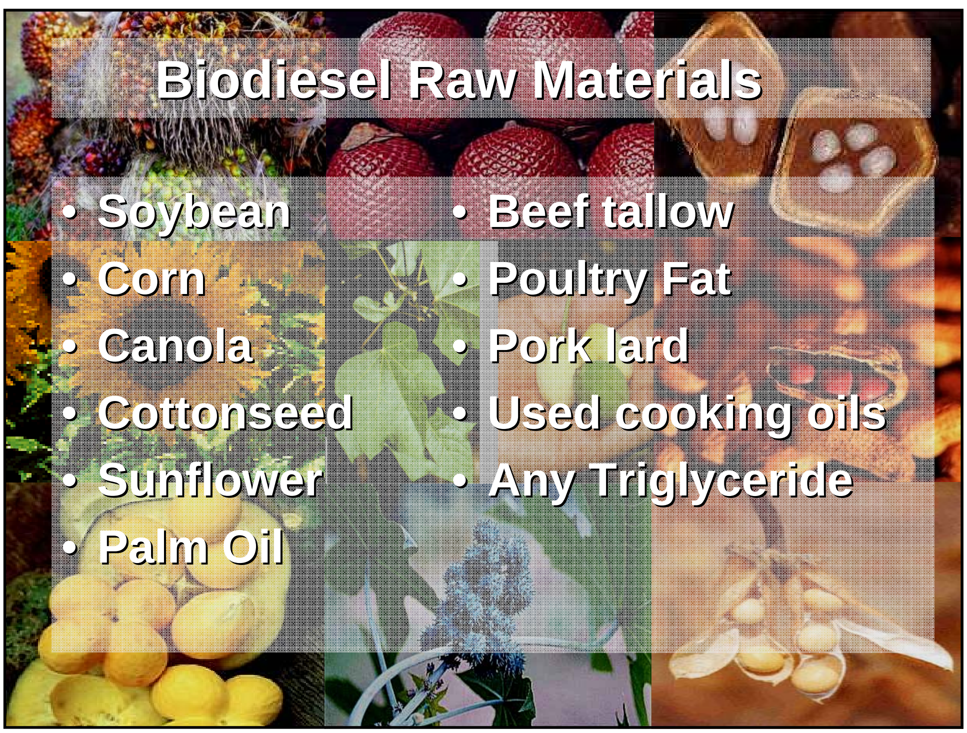
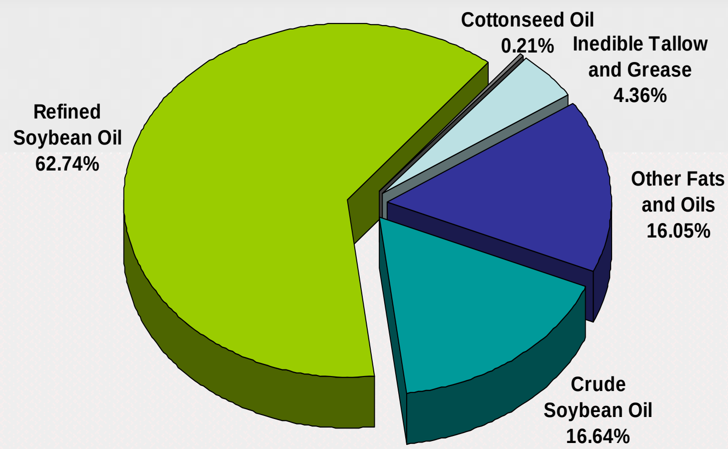
# Biodiesel Industry Update

March 26, 2008



# Raw Material Use - 2007

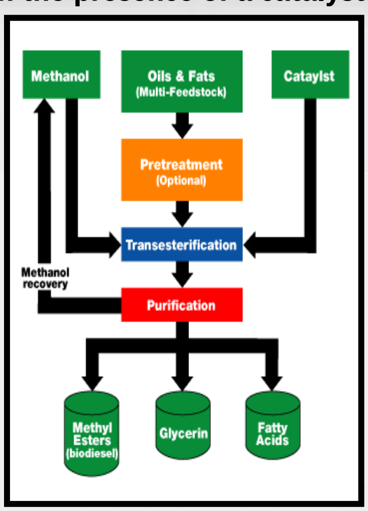



# The Biodiesel Reaction

**In the presence of a catalyst**

**Combining**

**Vegetable Oil**
**or**
**Animal Fat**
**(100 lbs.)**
**+**
**Methanol or**
**Ethanol**
**(10 lbs.)**



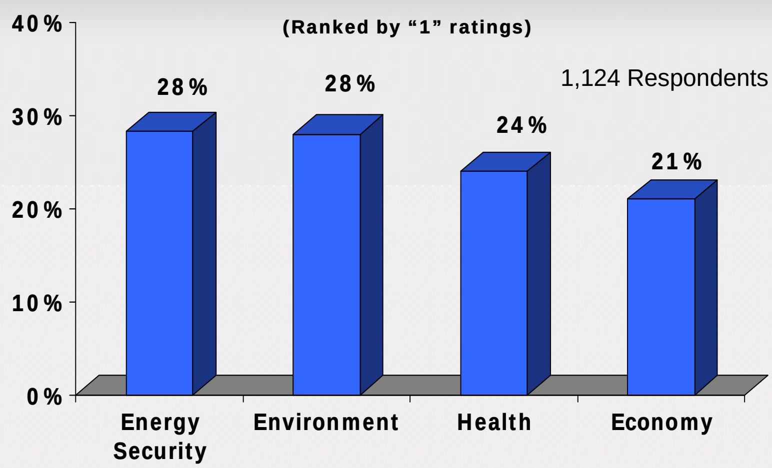

**Yields**

**Biodiesel**
**(100 lbs.)**
**+**
**Glycerine**
**(10 lbs.)**

## Benefits of Biodiesel

- Energy Independence
  - Domestically Produced rather than Imported
  - Biodiesel adds to fuel supply & adds refinery capacity
- Environment
  - biodiesel < virtually all regulated emissions
- Climate Change
  - biodiesel reduces lifecycle $CO_2$ by 78%
- Sustainability
  - highest energy balance of any fuel 3.5: 1
- Performance
  - higher oxygen, cetane, lubricity
  - lower sulfur, stability, cold flow

## Importance of Biodiesel Benefits for U.S. Consumers




National Survey conducted for the National Biodiesel Board in January 2008

# Biodiesel Markets

**ON-HIGHWAY USERS**
- Trucking
- Fleets
- Passenger Vehicles

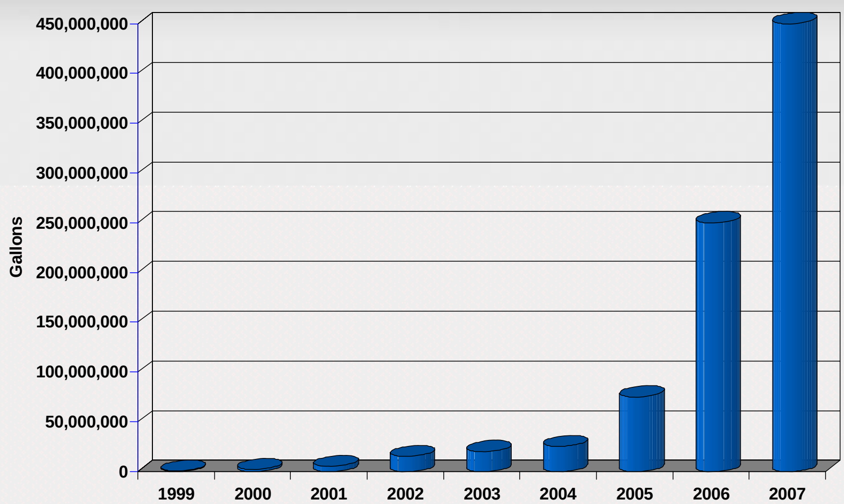
**REGULATED FLEETS**
- Federal
- State
- Selected Utilities

**HOME HEATING**

**MARINE**
- Recreational
- Tour Boats
- Environmentally Sensitive Areas

**AG AND OFF-ROAD USERS**
- Lubricity Enhancement

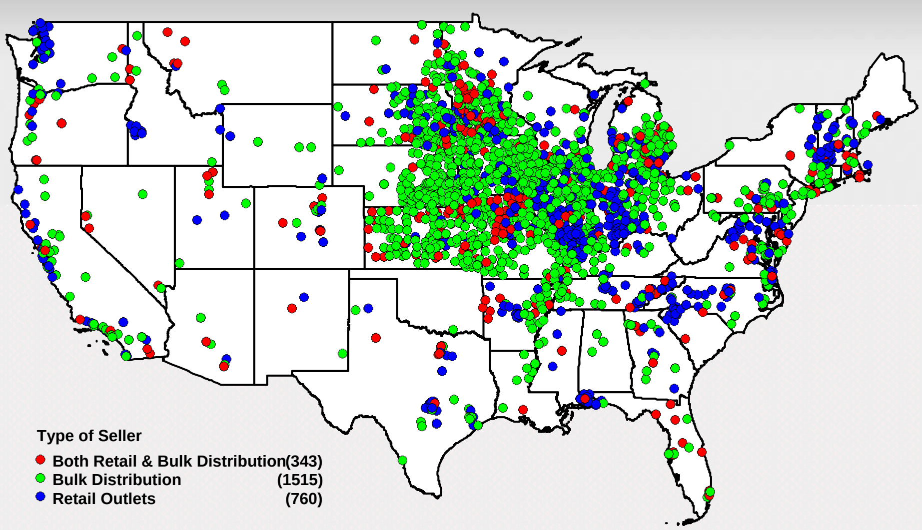
# US Biodiesel Demand



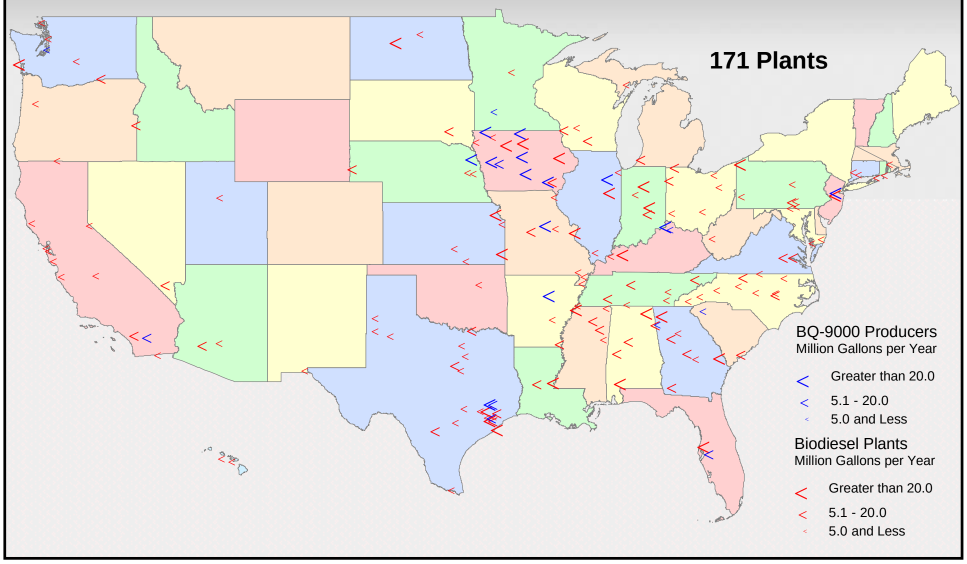
# Fuel Availability


- Fuel available through direct shipment or from over 1,860 petroleum distributors nationwide
- Over 1,100 retail filling stations nationwide
- Movement towards biodiesel at the terminal – over 37 terminal nationwide

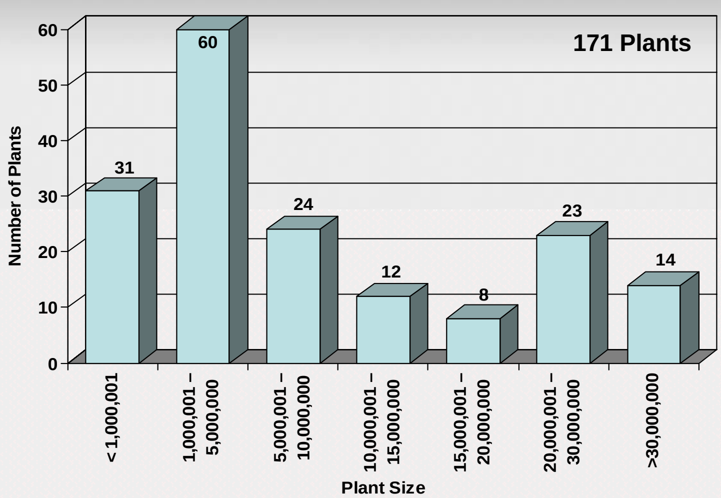
# Distribution Locations (Feb 2007)



## Production Locations (1/25/08)

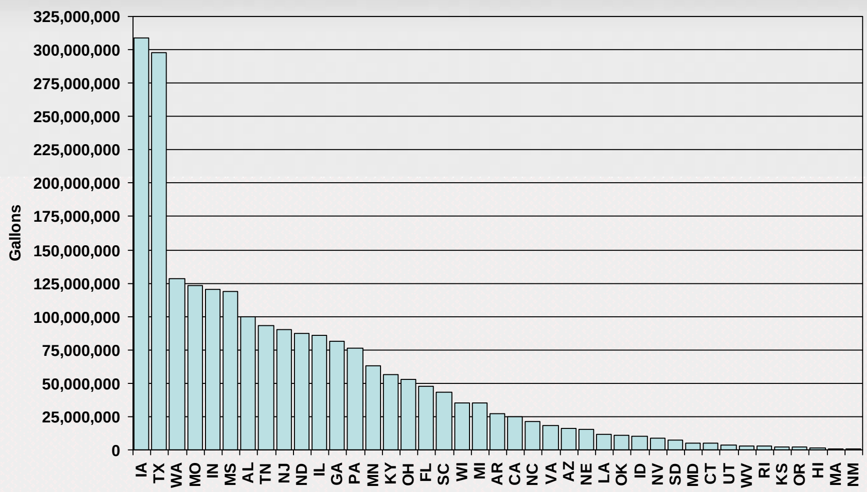



## Industry Plant Size

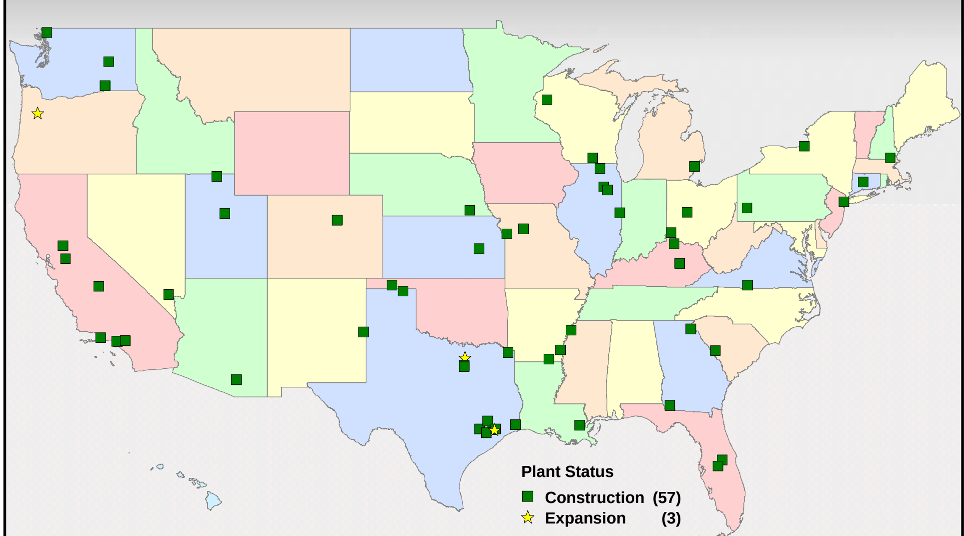



Production Capacity 2.24 billion gallons per year
Average Plant Size 13.1 million gallons per year

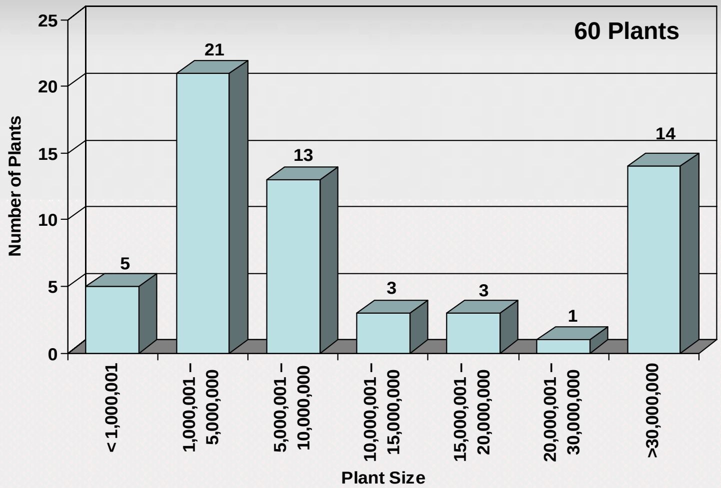
# Production Capacity by State (1/25/08)




# Biodiesel Plants Under Construction & Expansion (1/25/08)



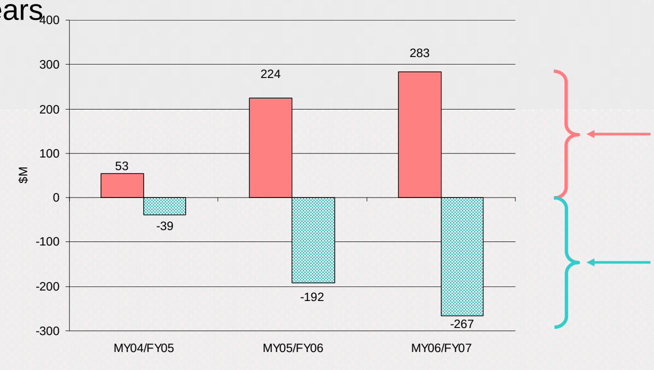
## Size of Plants Under Construction & Expansion




Construction Capacity 1.23 billion gallons per year
Average Plant Size 20.5 million gallons per year

## Government Program Payment Savings Compared to Biodiesel Tax Incentive

Resulting decrease in government program outlays for LDP due to biodiesel production (thus higher soybean prices) offsets about 90% of the Biodiesel Tax Incentive* outlays for all three years




Total Estimated Biodiesel Tax Incentive outlays for all 3 years - $561M

Total Estimated decrease in LDP outlays for all 3 years - $498M

* Assuming Biodiesel Tax Incentive became effective Jan 1, '05; $1/gal of soy-based biodiesel produced

# Annual Economic Impacts

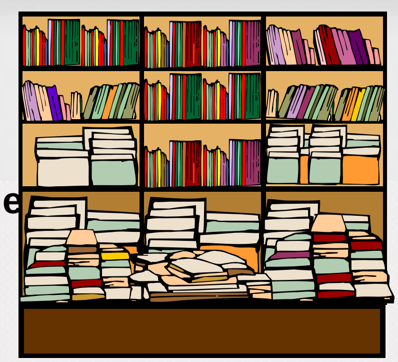
ECONOMIC IMPACT BY YEAR

| | Biodiesel Production (Mil gal) | New Spending (Mil 2007 $) | GDP Impact (Mil 2007 $) | Earnings Impact (Mil 2007 $) | Employment Impact Jobs |
|---|---|---|---|---|---|
| 2007 | 300 | $804 | $1,727 | $605 | 14,065 |
| 2008 | 350 | $937 | $2,009 | $704 | 15,965 |
| 2009 | 500 | $1,328 | $2,806 | $986 | 21,837 |
| 2010 | 650 | $1,713 | $3,565 | $1,257 | 27,249 |
| 2011 | 800 | $2,092 | $4,286 | $1,516 | 32,265 |
| 2012 | 1,000 | $2,593 | $5,230 | $1,857 | 38,855 |
| 2007-2012 | 3,600 | $9,468 | $19,623 | $6,925 | 38,855 |

# NBB Resources

www.biodiesel.org

- **Technical Library**
- **Biodiesel Bulletin**
- **Educational Videos Available**
- **Informational Resources**
- **Technical Resources**
- **On-line Database & Spec Sheets**



# Biodiesel SWOT Analysis

**Empower Commission Meeting**

**3/26/08**

## Biodiesel Strengths

- Lubrication qualities of biodiesel
- Biodiesel is environmentally friendly – emissions, carbon foot-print
- Positive conversion energy balance
- Variety of domestically grown feed stocks.
- Minimize dependence on foreign oil
- Renewable and domestic alternative to foreign oil
- Rural Economic development
- Aids in stability of production agriculture and minimizes federal farm program outlay
- Produces high value coproducts
- Good ND tax incentives

## Biodiesel Weaknesses

- High cost of feed stock
- Cold weather properties
- Lack of adequate distribution system
- Lack of knowledge about cold flow and storage properties
- Low utilization of production capacity
- Lack of production incentives in North Dakota
- No North Dakota certified lab - expensive
- Not all biodiesel is created equal
- Consistently meeting standards
- Lack of coproduct markets

## Biodiesel Opportunities

- High price of crude oil
- People would rather buy domestically made fuels
- Federal Renewable Fuel standard RFS2
- High demand for energy
- Engine manufacturer's acceptance of biodiesel
- California legislation – reducing carbon, companies reducing carbon footprint
- Developing markets – (reduced emissions) underground mining, cruise ships,
- International trade
- North Dakota can be a feedstock supplier
- Support ND petroleum industry to retail biodiesel
- ND legislators have opportunity to support biodiesel
- Coproducts can help build livestock industry

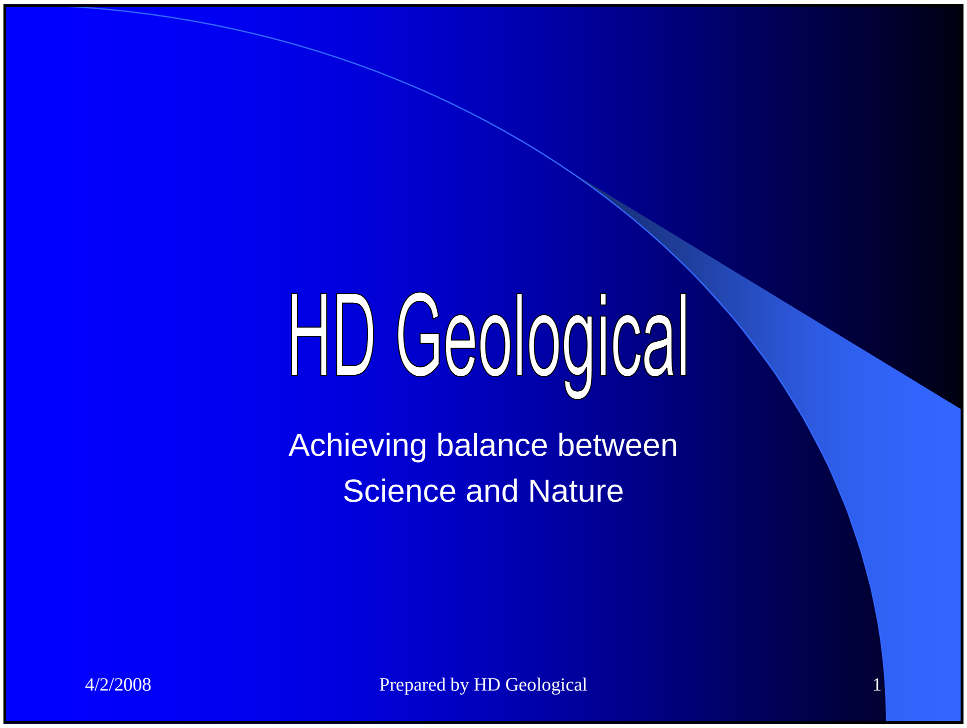
# Biodiesel Threats

- Inconsistent quality issues affecting public perception
- Government incentives are short-term
- Food vs. Fuel, indirect land use
- Incomplete trouble shooting of use problems
- Assumptions used in studies
- Manufacturers voiding warranties – requiring ASTM specifications
- Vegetable oil mix claiming to be biodiesel
- Methanol supply,
- High freight rates for biodiesel & rail car availability
- Green diesel
- Lack of distribution system

# BIODIESEL INDUSTRY

APPENDIX B

| STRENGTHS | WEAKNESSES |
|---|---|
| • Lubrication qualities of Biodiesel<br>• Biodiesel is environmentally friendly: Emissions & Carbon foot print<br>• Positive conversion energy balance<br>• Variety of domestically grown feed stock<br>• Reduces the US dependence on foreign oil<br>• Renewable & domestic fuel<br>• Rural economic development<br>• Stabilizes production agriculture & minimize federal funding of farm budget outlays<br>• Produces high value co-products<br>• Good North Dakota tax incentives | • High feed stock costs - Negative Margins<br>• Cold weather properties<br>• Lack of adequate distribution and blending infrastructure<br>• Cold flow and storage properties – lack of understanding<br>• Low utilization of existing production capacity<br>• Limited state incentives - Consumption incentive? Production incentives?<br>• No North Dakota state certified lab - expensive<br>• Inconsistent quality – Meeting ASTM D 6751 minimally is imperative<br>• Not all biodiesel is created equal – how green is green<br>• Lack of co-product markets |
| **OPPORTUNITIES** | **THREATS** |
| • The high price of crude oil<br>• Increasing energy demand – Buy American<br>• Lessens foreign energy dependence<br>• RFS2, Renewable Fuels Standard, 36 BGal. by 2022,<br>• Fed Govt. mandate in current Energy Bill - 1BG 2012<br>• Engine manufactures warranty Biodiesel<br>• California legislation – Reducing carbon<br>• Clean Air Act - Reduced sulfur in diesel<br>• Developing markets, underground mining, marine, bus<br>• International trade<br>• Industry, environmentalists, politicians & farmers<br>• North Dakota feed stock supplier<br>• Support ND petroleum industry to retail biodiesel<br>• North Dakota legislation could support Biodiesel<br>• Co-products can help build ND livestock/feed industry | • Incentives can be eliminated by a stroke of the pen<br>• Inconsistent quality issues affecting public's perception<br>• Ultra-Low sulfur diesel problems attributed to Biodiesel<br>• Short term guarantee on federal government incentives<br>• Other states having production incentives<br>• Food vs. fuel debate – Higher food costs<br>• Lack of distribution and blending infrastructure<br>• Indirect land use affects – Acres competition<br>• Incomplete trouble shooting – Assumptions used in studies<br>• Engine manufactures voiding warranties – req. ASTM specs<br>• New technology<br>• Green diesel<br>• Vegetable oil mixes claiming to be biodiesel<br>• Splash & Dash vessels to EU<br>• Methanol supply<br>• Railroad companies |


HD Geological
Achieving balance between
Science and Nature
4/2/2008
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REFINING OPPORTUNITIES
IN
INDIAN COUNTRY
4/2/2008
Prepared by HD Geological
2

## Mission

- To establish a commercially viable, clean fuels industrial development at your Reservation
- To provide technical training and long-term jobs for the local population



## Crude Oil Refinery Defined

- An industrial tool to clean, separate and then upgrade raw crude oil into usable components
- Commercially viable,independent business entity
- Consists of clean-up units to extract contaminants
- Consists of primary(separation) and secondary(upgrading) process units to produce finished products for consumer use

## WHY BUILD A REFINERY IN INDIAN COUNTRY ?

- U.S. imports 2.35 million barrels per day of crude oil products
- Refineries in U.S. operating at 98% capacity
- U.S. refining capacity is insufficient to supply market demand
- Existing refineries must invest more capital to meet pending effluent limitations and product specifications
- Federally Recognized Indian Tribes have unique tax advantages
- U.S. needs product./Tribes can provide it.



## CRITERIA NEEDED

- Commitment and vision from the Tribe
  - majority support from council
  - community support
  - obtain knowledgeable consultant
  - selection of experienced engineering firm
  - selection of qualified environmental company

## Front End Engineering and Design Environmental Impact Statement

- FEED Study
  - Performed by Engineering Firm
  - Design and layout of proposed project
  - Marketing and Business Plan
- EIS Study
  - Completed by Environmental Company
  - Answer all NEPA and EPA Questions
  - Obtain all needed permits for construction



## INFRASTRUCTURE

- Feedstock
- Utilities
- Road
- Rail
- Product Distribution

## OIL/GAS PRODUCTION

- Ownership by Tribe an advantage
- Pipeline



## ACCESS to MARKETS

- Gasoline
- Diesel
- Jet Fuel
- Propane

## SITE LOCATION

- 320 (+) acres site
  - able to acquire permits
  - trust land preferred (not mandatory)



## TRAINING PROGRAMS

- Produce Qualified Tribal Members
  - Take ownership of project
  - Utilize local Tribal College
  - Create employment, quality jobs



## JOBS

- Building trades for 24 (+/-) months construction
- Maintenance
- Plant Operation
  - Management
  - Marketers
  - Plant Operators
  - Laboratory Technicians
  - Pipe Fitters & Welders
  - Electricians & Instrument Technicians
  - Accountants
  - CAD Designers

# REFINERY COMPLEX

- 15,000 BPSD Refinery and Tankage on 320 acre site
- Office complex
  - Corporate
  - Supply and Transportation
  - Marketing and Accounting
- Laboratory
- Training Center
- Central Control Building
- Operating Staff of 65 + Maintenance Trades



# FUNDING SOURCES and OPPORTUNITIES

- FEDERAL GRANTS
- PRIVATE INVESTMENT GROUPS

## GRANTS

- Tribes have access to Government entities
  - Bureau of Indian Affairs
  - Department of Energy
  - Department of Commerce
  - USDA



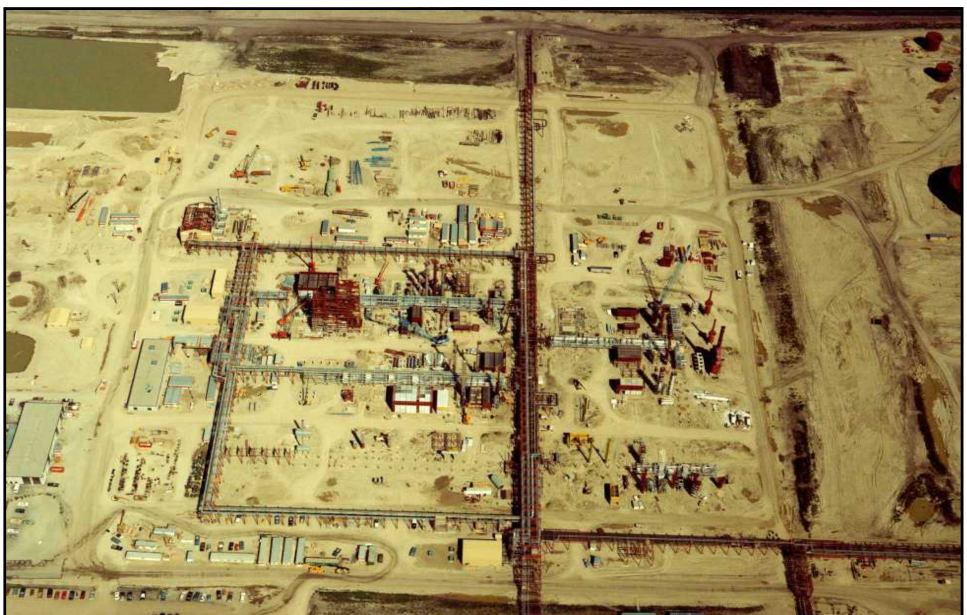
## PRIVATE INVESTMENT GROUP

- Money Readily Available
- Tribes and Investors Structure Deal
- Find Terms "Comfortable" for both parties

Last Grass Roots Refinery Built in North America
Construction Started September 1980

Grass Roots Modular Refinery Project: Site Preparation, April 1981

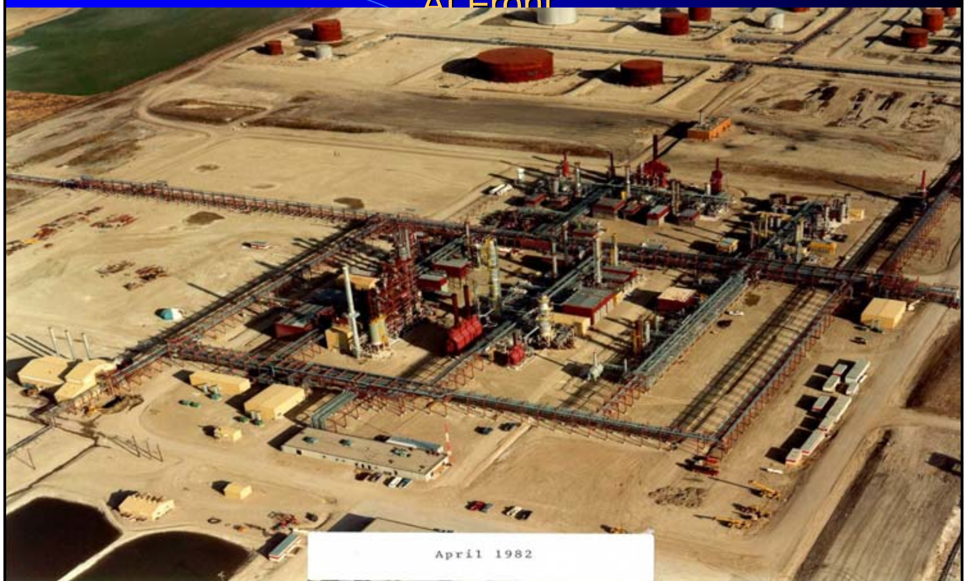
4/2/2008 Prepared by HD Geological 19



Grass Roots Modular Refinery Project: Taking Shape, July 1981

4/2/2008 Prepared by HD Geological 20

## Process Area Nearly Complete, Control Room At Front






## October 1982 - Refinery In Full Operation

## REFINERY MODULE SHOP ASSEMBLED, TRUCKED TO THE SITE



## SUMMARY

- Opportunities for Tribes to:
  - Form partnerships
  - Exercise sovereignty
  - Economic development
  - Training and employment for Tribal members
  - Tribes able to help the country by providing a much needed product
  - Tribally owned corporation has competitive advantage in the industry

Grass Roots Modular Refinery Project: Thirteen Month's Progress, October 1981

September 2003 Prepared by MHA Nation, Triad, Greystone 22

4/2/2008 Prepared by HD Geological 25

# NEPA Compliance

- Prepare Environmental Impact Statement (EIS)
- Scoping
- Draft EIS
- Public Review of Draft EIS
- Final EIS
- Record of Decision

September 2003 Prepared by MHA Nation, Triad, Greystone 36

4/2/2008 Prepared by HD Geological 26

## Major Approvals and Permits

- BIA — NEPA Compliance for Fee-to-Trust Transfer of Land Ownership
- EPA (Region 8) — Clean Air Act, Clean Water Act, and NEPA Compliance
- FWS —Endangered Species Act Compliance
- TCPO — Historic Preservation Act Compliance
- USACE — Clean Water Act, Section 404 Compliance

September 2003 | Prepared by MHA Nation, Triad, Greystone | 35

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# Status Report

## Lignite Research Council

### Potential for Co-firing Biomass with Lignite in North Dakota

February 12, 2007

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## Study Outline

- Survey of North Dakota's Biomass Inventory
  - Switchgrass and perennial grasses
  - Crop residues: Wheat straw, Corn stover
  - Forest and urban wood wastes - RDF
- Survey of Biomass & Coal Co-firing in Europe and North America
  - Europe – Straw at Dong Energy, Denmark
  - U.S. – Switchgrass - Ottumwa Generating Station, Iowa
- Potential for Biomass Co-firing with Lignite Opportunities in North Dakota
  - PC fired plants
  - Other CFB, FB

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## Reasons for Co-firing in ND

- Available Biomass Supply - Existing studies indicate in excess of 200,000 tpy/plant or 37 MWe
- Lowest cost starting point to build biomass feedstock infrastructure.
- Minnesota Global Warming Mitigation Act (SF 192)
- Renewable Energy Certificates (REC)
- $CO_2$ Credits (CCX $3.50/ton $CO_2$ if no RECs)
- $SO_2$ Emissions Reductions ($600/ton $SO_2$)
- State Renewable Energy Production Tax Credits
- Federal Production Tax Credits
- Green Power sales (If applicable)

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## Potential ND Energy Crops**

| Power Stations | Switchgrass in Dry Tons/yr | Poplar in Dry Tons/yr |
|---|---|---|
| Coyote Station, Antelope Valley Station & Great Plains Synfuels Plant | 1,360,430 | 330,763 |
| Milton R Young Station | 1,316,890 | 347,255 |
| Coal Creek Station | 1,681,300 | 373,648 |
| R.M. Heskett Station | 679,086 | 275,753 |
| Stanton Station & Leland Olds Station | 1,198,757 | 338,474 |

**U.S. Dept of Energy Study, 2006

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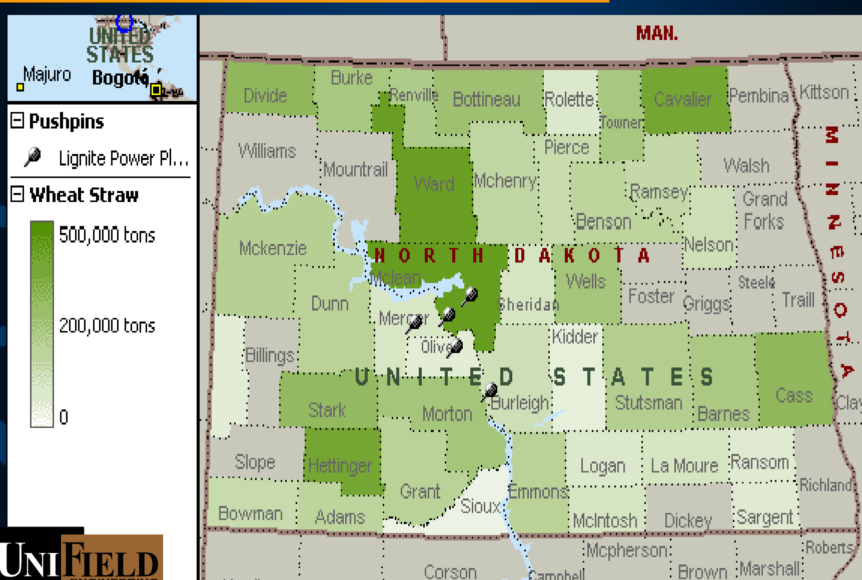
# ND Biomass: Wheat Straw**

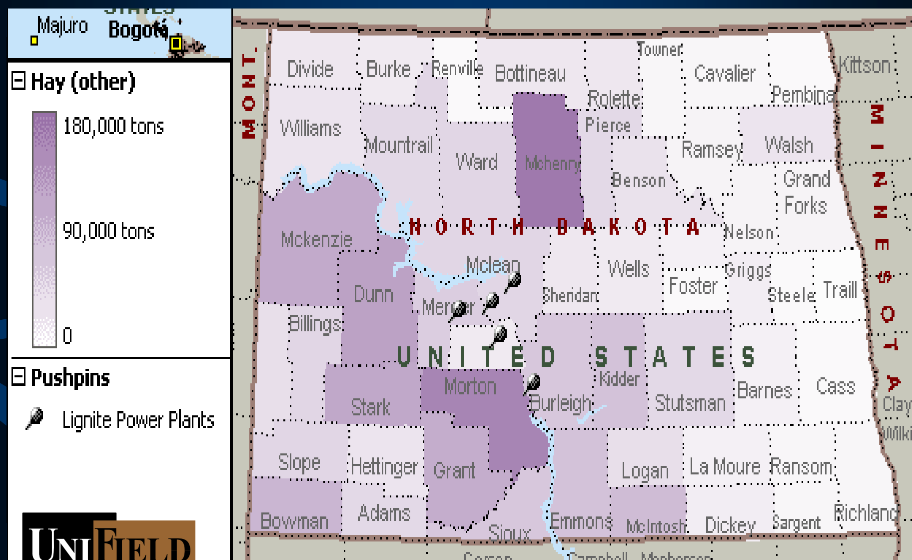
| Power Stations | Max dry tons | Conventional dry tons | Mulch dry tons | No-Till dry tons |
|---|---|---|---|---|
| Coyote Station, Antelope Valley Station & Great Plains Synfuels Plant | 691,019 | 505,569 | 641,765 | 674,741 |
| Milton R Young Station | 574,113 | 407,011 | 527,857 | 558,724 |
| Coal Creek Station | 740,074 | 569,819 | 695,823 | 725,541 |
| R.M. Heskett Station | 506,766 | 358,836 | 468,386 | 494,804 |
| Stantion Station & Leland Olds Station | 565,029 | 417,472 | 524,289 | 551,504 |

**U.S. Dept of Energy Study, 2006

# ND Supply – Wheat Straw



# ND Supply – Hay, Per. Grasses

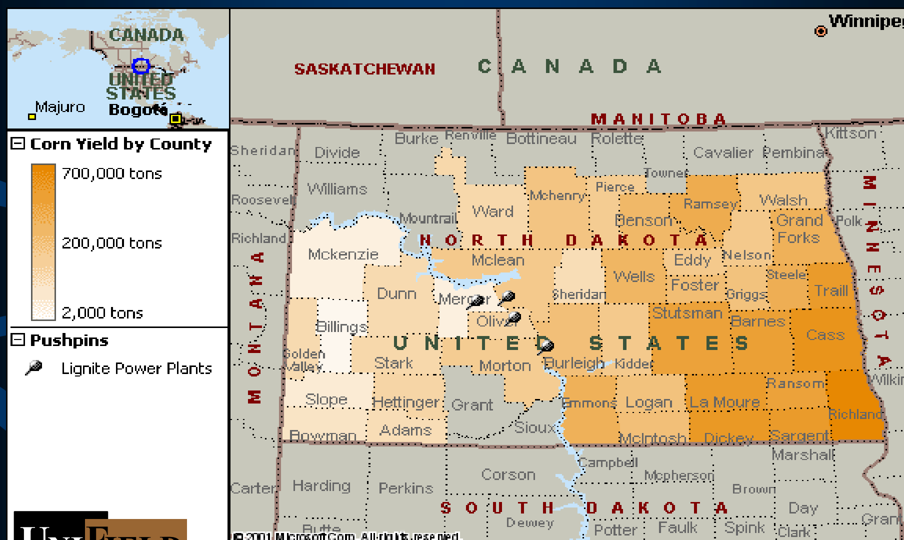



# ND Biomass: Corn Stover**

| Power Stations | City | Current Tillage in dry tons | All Land in No Till in Dry Tons |
|---|---|---|---|
| Coyote Station, Antelope Valley Station & Great Plains Synfuels Plant | *Beulah* | *63,000* | *1,147,000* |
| Milton R Young Station | *Center* | *84,000* | *1,524,000* |
| Coal Creek Station | *Underwood* | *306,000* | *5,086,000* |
| R.M. Heskett Station | *Mandan* | *351,000* | *5,750,000* |
| Stanton Station & Leland Olds Station | *Stanton* | *63,000* | *1,147,000* |

**U.S. Dept of Energy Study, 2006

# ND Supply - Corn Residues




# ND Biomass: Forest & Urban Residues**

| Power Stations | Total Forest Residues (dry tons) | Urban Residues: Demolition (dry tons) | Urban Residues: Construction (dry tons) | Urban Residues: Total construction & demolition (dry tons) |
|---|---|---|---|---|
| Coyote Station, Antelope Valley Station & Great Plains Synfuels Plant | 24,241 | 374,312 | 4,958 | 379,270 |
| Milton R Young Station | 28,730 | 372,610 | 4,943 | 377,553 |
| Coal Creek Station | 29,399 | 397,017 | 5,236 | 402,253 |
| R.M. Heskett Station | 27,759 | 271,949 | 3,664 | 275,614 |
| Stanton Station & Leland Olds Station | 23,225 | 368,427 | 4,887 | 373,314 |

**U.S. Dept of Energy Study, 2006

## Other North Dakota Biomass

- Sugar beet pulp from Red River refiners
- DDG from ethanol
- Municipal solid waste - RDF
- Soybean hulls
- Municipal wastewater sludge

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## Coal/Biomass Co-firing Worldwide

- 16 countries (11 in Europe)
- Direct co-firing more than 10 years in some countries (Denmark, Holland)
- 135 plant tests (40 in US)
- Most Direct fired PC
- Less than 10% biomass by heat input (Usually 5% )
- Fuel processed through existing mills

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## Plants Co-firing Lignite/Biomass

| Country | Germany | Germany | Thailand | USA |
|---|---|---|---|---|
| Location | Lubbenau | Schwandorf | Chiang Mai | Bismarck |
| Owner | VEAG | Bayernwerke | Electric Authority | ND Corrections |
| Co-fireType | Direct | Direct | Direct | Direct |
| Boiler | PF | Grate | CFB | Grate |
| Burner | Wall fired | | | Traveling grate |
| Out MWe | 100 | | 20 | |
| Out MWth | | 280 | | 28 kpph 200psig |
| Fuels | Wood, straw | Wood, straw pellet | RDF | Wood |

## Test Co-firing Low-Quality Fuels

- Greece - lignite
- Germany – lignite
- Australia – brown coal

## Commercial Challenges

- Uncertain long term biomass fuel supply
- Lack of clear/reliable policy frameworks
- Ash utilization options uncertain
- Changes in legislative position requires modified environmental permits

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## Holland – Multiple Plants

- 400 MWe cofiring capacity in 7 plants.
- 4 plants operating each 150,000 tpy
- Direct cofiring up to 10% daily practice
- Next step indirect cofiring to 20%
- Indirect cofiring with CFB-type gasifier
- Fuels: Demolition wood, paper sludge, wood pellets, palm kernels, animal fat, poultry litter, sewage sludge.

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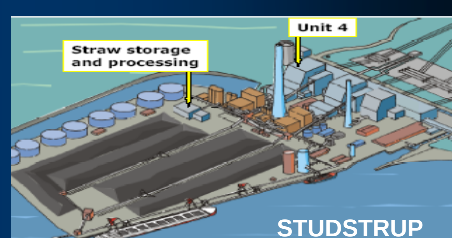
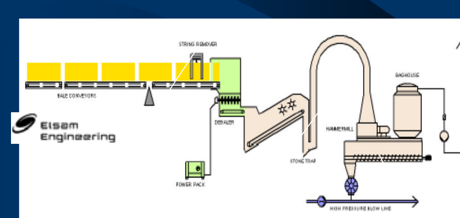
# Holland – Technical Concerns

- Fuel handling, storage and spontaneous combustion
- Miling and drying
- Combustion reactivity and particle size distribution
- Fouling and slagging – alkali and chlorides
- Thermal behavior of boiler
- Corrosion/erosion rate
- By product quality free CaO and soluble PO4
- Emission to atmosphere
  - <CO2, <SO2
  - SCR deactivation
  - Emission control capacity

# Denmark Straw Co-firing - 200,000 tpy

- **1993-1995 Short term tests & 20% straw demo 150 MWe CHP**
- **1998-2001 Flyash acceptance**
- **2001 Conversion Unit 4**
- **2002-2004 Commercial operation 10% (20 tph) 350 MWe CHP PC Wall Fired**
- **4 burners - 4 lines 5 tph each**
- **90% Availability**
- **95% of problems are in straw milling (2006)**



## Conclusions – Co-firing in Europe

- Direct co-firing is cheapest method
- High efficiency and proven at up to 10%
- Strong economic & regulatory incentives in place
- Gasification-based co-firing more expensive but cheaper than stand alone gasification plants
- Gasification increases substitution with dirtier fuels
- May be a strategic interim step toward cellulosic liquid fuels production
- Most promising concepts:
  - Upstream gasification without low temp fuel gas cleanup
  - Biomass upgrading to other products

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## U.S. Switchgrass Co-firing, 2006

- Ottumwa Station, Iowa
  - Alliant Energy / Mid-American
  - 726 MW, PRB Coal, 1982 startup
  - Twin furnace T-fired PC boiler
  - 2.5 to 5% heat input from switchgrass
  - Separate biomass injection, 2 - 4 ports
- Long Term Test Objectives (Mar-May)
  - 2000 hr continuous test
  - Investigate fouling, slagging, and corrosion
  - Operational costs for business planning
  - Burn up to 25,000 tons of switchgrass

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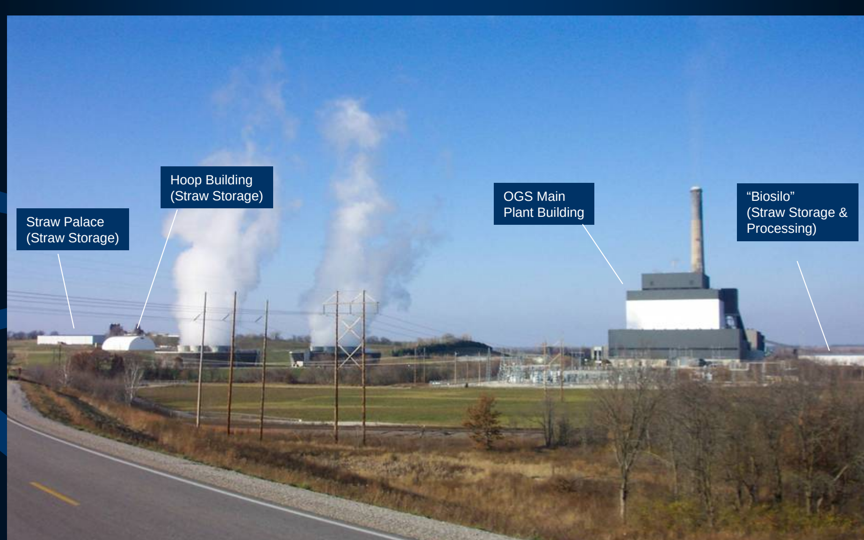
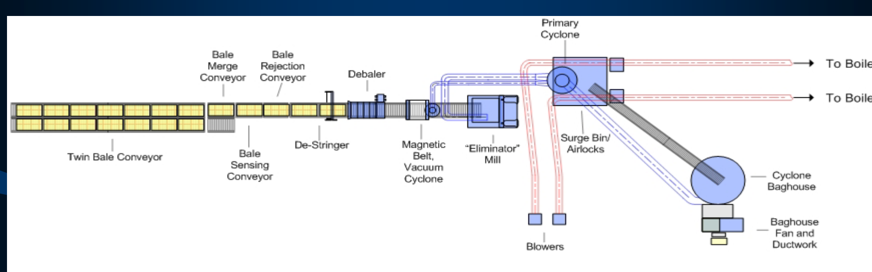
# Harvest, Collection, Storage

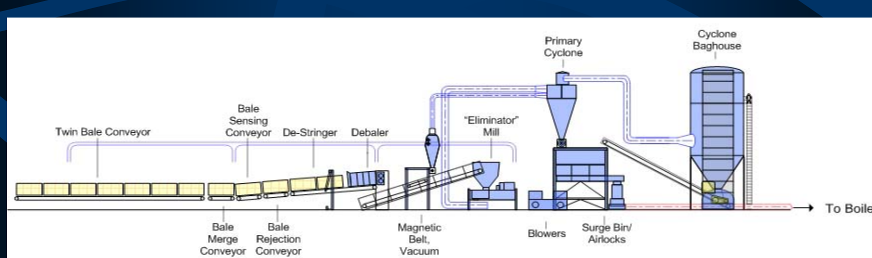
# Ottumwa Facilities at OGS



# Processing & Fuel Delivery

# Switchgrass Processing at OGS



# Process Equipment

*Debaler Hammers 30,000 t/set*
*Screens 8,000 t/set*

*Steffen Systems 2 t Bale Hooks*

*Attrition hammers 7,000 t/set*

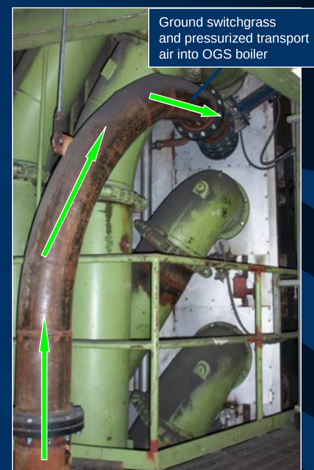
*400hp De-baler 12tph, 2in screen, Warren & Baerg*

# Back End of Processing System

- 2-stage milling process to reduce particle size
- Final product fed into 2 blow lines to boiler

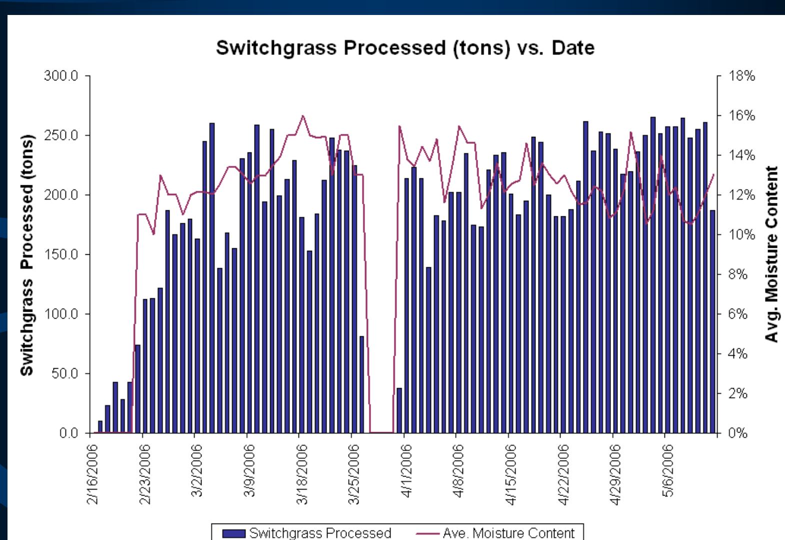
- High-efficiency cyclone and baghouse for dust control and filtering

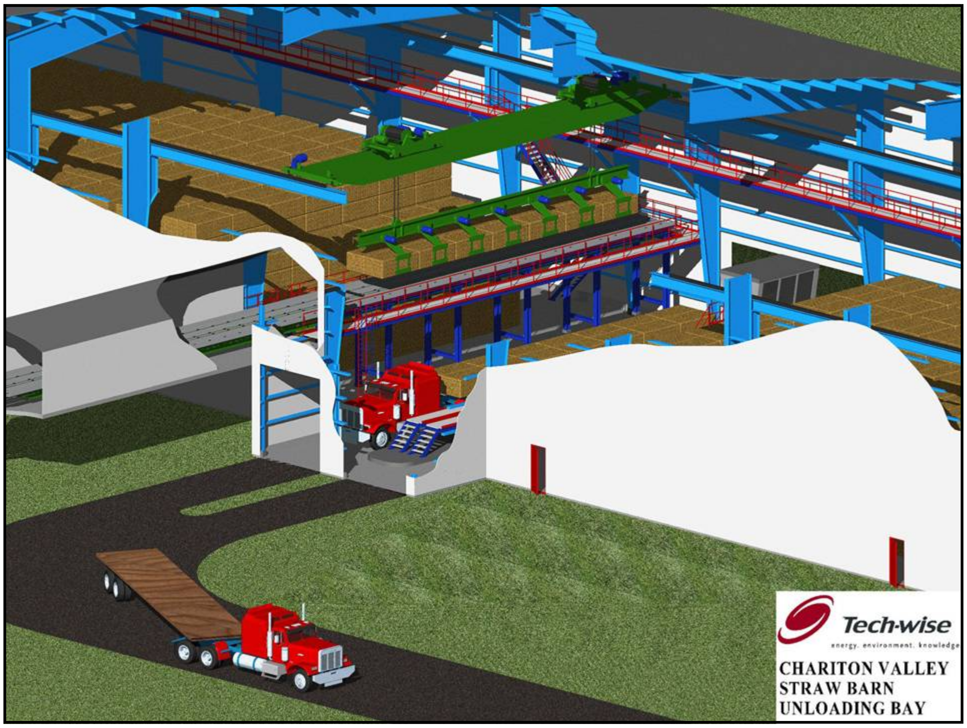
# Pneumatic Transport to Boiler

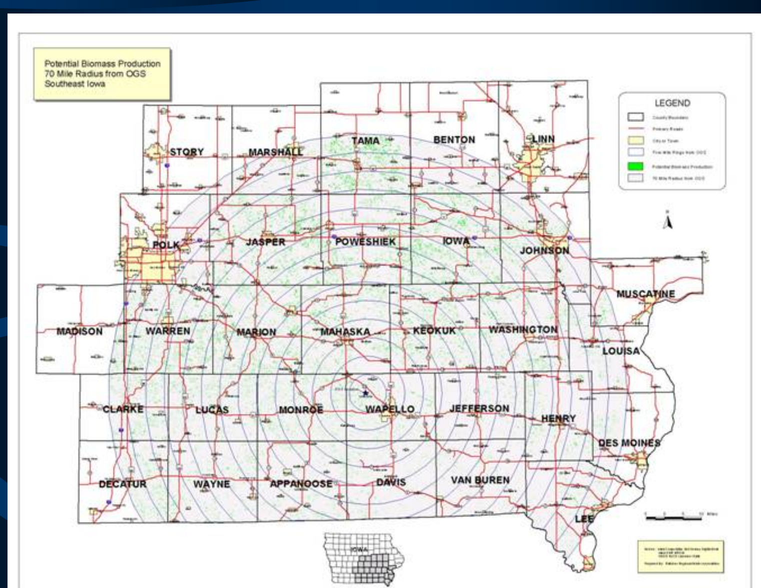

**Pneumatic lines transporting ground switchgrass into boiler house (left) and boiler (right).**

# Daily Production






## Switchgrass on CRP - 70 Mile Radius



## Ottumwa Conclusions

- Emissions
  - Reduced $SO_2$
  - Neutral on $NO_x$
  - Reduced $CO_2$
  - Neutral on CO (OGS has extremely low CO)
  - Increased Opacity (about 1 percentage point)
    - Required higher soda ash addition rates during test
- Other
  - Minimal Impact on Heat Rate (in the “noise”)
  - Some unburned biomass in bottom ash
  - No significant impact on LOI in fly ash
  - Bale moisture, weed content, package quality has large impact on processing achievable rates

UNIFIELD ENGINEERING

## ND Study Completion

- Biomass Inventory Completion – Feb 07
- Station Documentation – Feb/Mar 07
- Submittal & Review – Mar 07

UNIFIELD ENGINEERING

# Dickey-LaMoure Bio-energy Industrial Park Design

Summary of Final Study Report

March 26, 2008

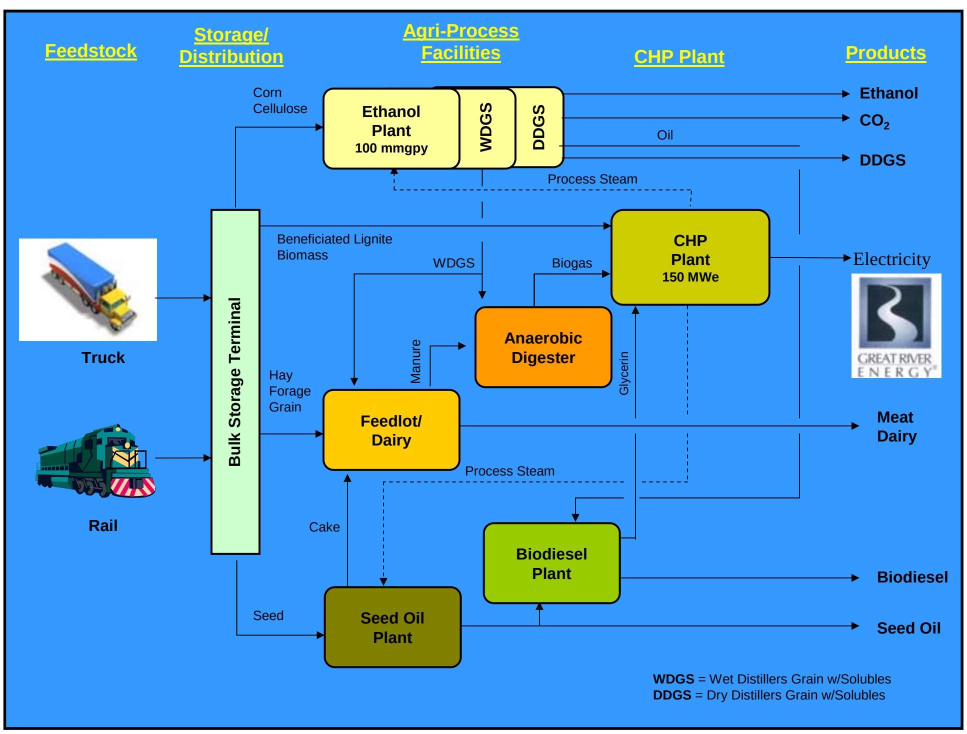
Empower North Dakota Commission

## Sponsors

- Great River Energy
- Dakota Renewables
- James Valley Grain
- DMVW Railroad
- Edgeley Development
- Oakes Enhancement, Inc.
- RRV W Railroad
- Scott Financial
- Westgate Energy

# Bio-industrial Park Vision

- Fuel Ethanol Facility (dry mill) -110 mmgpy
- Fuel Ethanol Facility (cellulosic)-70 mmgpy
- Bio-diesel Facility- 30 mmgpy
- Seed Oil Crushing Facility – 30 mmgpy
- Anaerobic Digestion Facility – Sized for 100 mmgpy dry-mill ethanol facility
- Feedlot/Diary – 10,000 head



## Site Selection Criteria

- Coal Delivery Cost
- Natural Gas Delivery Cost
- Electric Transmission
- Product Shipping
- Wastewater Discharge
- Community and Govt. assistance
- Proximity of class 1 highway
- Proximity of Railroad
- Potential adverse affect on Population Center
- Future Expansion/Land Availability

## Fatal Flaw Criteria

- 480+ contiguous acres available
- Located away from any environmentally sensitive area
- Unit train accessible
- Electric power transmission near
- Zero liquid discharge not a site limit
- Adequate water supply
- No-load restricted roads within 3 miles

## Conclusions

- Vision is sound
- Overall timeframe will accommodate development of Cellulosic Ethanol
- Other Ag processes are existing and well established
- Resolve water and wastewater issues before site selection and purchase
- Economics require steam contracts before final site selection and go decision

## Next Steps

- Hold Sponsor meeting to review results and decide on course of action
- Monitor impact of $CO_2$ regulation on CHP
- Build partner relationships for Ag partners
- Monitor MISO queue for transmission connection and service application
- Monitor commodity markets

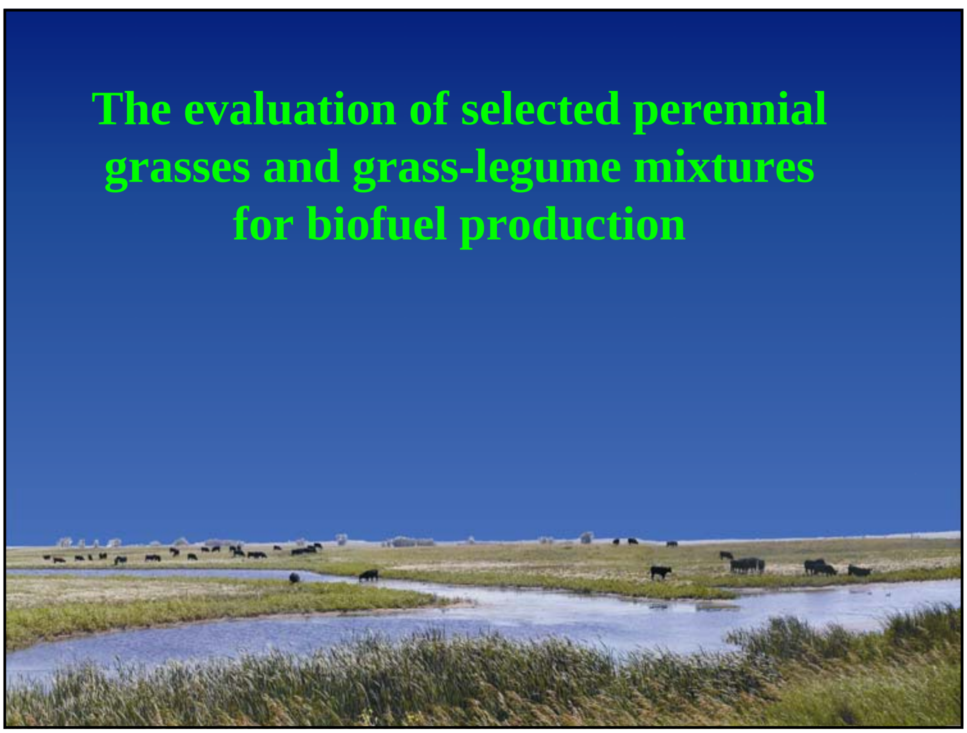
# The Production of Perennial Forages for Biofuels

Paul E. Nyren
Central Grasslands Research Extension Center

## Biomass Power – Back to the Future

- 1920 – 27,000,000 horses & mules in USA
- 1954 - < 5,000,000
- Resulted in major land use change. 80,000,000 acres of pasture & hayland (biomass) released for other uses
- If we are to reach the federal governments goal of 1 billion tons of biomass for ethanol by 2030 then we will see a similar land use change again.


A study in cooperation with the USDA-ARS in Lincoln Nebraska was started in 2002 to evaluate the production and economics of raising switchgrass for ethanol.


The evaluation of selected perennial grasses and grass-legume mixtures for biofuel production

# Research Objectives

- Determine the biomass yield and select chemical composition of perennial herbaceous crops at several locations throughout central and western North Dakota

# Research Objectives

- Determine the optimum harvest dates for maximum biomass yield and maintenance of the stands.

# Research Objectives

- Compare annual and biennial harvest on total biomass yield and maintenance of the stands.

# Research Objectives

- Evaluate carbon sequestration and storage of the various perennial crops

# Research Objectives

- Evaluate the economic feasibility of the various perennial herbaceous energy crops with competing crops in the surrounding area.

# Funding provided by the following:

North Dakota Natural Resources Trust
NDSU Agricultural Exp. Station
USDA-ARS Northern Great Plains Research Laboratory
ND Game and Fish Department
ND Department of Commerce
ND Farmers Union
Jamestown/Stutsman Development Corporation
Dakota West RC&D
Dakota Prairie RC&D
Natural Resources Conservation Service (NRCS)

## Funding provided by the following:

- ND Farmers Union
- Jamestown/Stutsman Development Corporation
- Dakota West RC&D
- Dakota Prairie RC&D
- Natural Resources Conservation Service (NRCS)

## Plot Locations

- Hettinger REC
- Williston REC, Dryland and Irrigated
- North Central REC, Minot
- Carrington REC
- Central Grasslands REC, Streeter

# Experimental Design

## harvested annually and biennially

- Sunburst Switchgrass
- Trailblazer Switchgrass (Hettinger, CGREC, & Carrington)
- Dakota Switchgrass (Williston & North Central)
- Alkar Tall Wheatgrass
- Haymaker Intermediate Wheatgrass
- CRP Mix (Intermediate + Tall Wheatgrass)

- CRP mix (Intermediate + Tall + Alfalfa + Sweetclover)
- Sunburst Switchgrass + Tall Wheatgrass
- Sunburst Switchgrass + Sunnyview Big Bluestem
- Sunburst Switchgrass + Mustang Altai Wildrye
- Magnar Basin Wildrye + Mustang Altai Wildrye

**Soil samples were taken prior to seeding by researchers Kristy Nichols and Mark Halverson of the USDA-ARS Field Laboratory in Mandan.**

**Plots are 15’ X 30’ replicated 4 times, seeded with a cone seeder specially designed for seeding grasses and legumes**

2007 yields on the dryland plots at Hettinger. All yields at each location followed by the same letter are not significantly different at the .05 level.

| Site Species | YieldT/AC | |
|---|---|---|
| CRP Mix (Wheatgrasses +alfalfa+Swt.clover) | 1.8 | a |
| Alkar Tall Wheatgrass | 1.5 | a |
| CRP Mix (Intermediate & Tall Wheatgrass) | 1.5 | ab |
| Sunburst Switchgrass + Tall Wheatgrass | 0.9 | abc |
| Haymaker Intermediate Wheatgrass | 0.8 | abc |
| Magnar Basin + Mustang Alti wildrye | 0.4 | bc |
| Trailblazer Switchgrass | 0.0 | c |
| Sunburst Switchgrass + Mustang Alti wildrye | 0.0 | c |
| Sunburst Switchgrass + Sunnyview Big Bluestem | 0.0 | c |
| Sunburst Switchgrass | 0.0 | c |
| LSD 0.05 | 1.07 | |

2007 yields on the dryland plots at Williston. All yields at each location followed by the same letter are not significantly different at the .05 level.

| Site Species | YieldT/AC | |
|---|---|---|
| Haymaker Intermediate Wheatgrass | 1.2 | a |
| CRP Mix (Intermediate & Tall Wheatgrass) | 1.1 | a |
| Alkar Tall Wheatgrass | 1.0 | a |
| Sunburst Switchgrass + Tall Wheatgrass | 1.0 | a |
| CRP Mix (Wheatgrasses +alfalfa+Swt.clover) | 0.8 | ab |
| Sunburst Switchgrass + Mustang Alti wildrye | 0.3 | bc |
| Dakota Switchgrass | 0.3 | bc |
| Sunburst Switchgrass + Sunnyview Big Bluestem | 0.3 | bc |
| Magnar Basin + Mustang Alti wildrye | 0.3 | bc |
| Sunburst Switchgrass | 0.1 | c |
| LSD 0.05 | 0.62 | |

2007 yields on the dryland plots at Carrington. All yields at each location followed by the same letter are not significantly different at the .05 level.

| Site / Species | YieldT/AC | |
|---|---|---|
| Trailblazer Switchgrass | 6.1 | a |
| Sunburst Switchgrass | 5.4 | ab |
| Sunburst Switchgrass + Sunnyview Big Bluestem | 5.4 | ab |
| Sunburst Switchgrass + Tall Wheatgrass | 5.1 | bc |
| Sunburst Switchgrass + Mustang Alti wildrye | 5.1 | bc |
| Alkar Tall Wheatgrass | 4.7 | bcd |
| CRP Mix (Wheatgrasses +alfalfa+Swt.clover) | 4.6 | bcd |
| Haymaker Intermediate Wheatgrass | 4.5 | cd |
| CRP Mix (Intermediate & Tall Wheatgrass) | 4.3 | d |
| Magnar Basin + Mustang Alti wildrye | 4.0 | d |
| LSD 0.05 | 0.77 | |

2007 yields on the dryland plots at Minot. All yields at each location followed by the same letter are not significantly different at the .05 level.

| Site Species | YieldT/AC | |
|---|---|---|
| Alkar Tall Wheatgrass | 4.5 | a |
| CRP Mix (Intermediate & Tall Wheatgrass) | 4.2 | ab |
| Sunburst Switchgrass + Tall Wheatgrass | 4.2 | ab |
| CRP Mix (Wheatgrasses +alfalfa+Swt.clover) | 3.8 | ab |
| Haymaker Intermediate Wheatgrass | 3.3 | bc |
| Sunburst Switchgrass + Mustang Alti wildrye | 2.6 | cd |
| Magnar Basin + Mustang Alti wildrye | 2.6 | cd |
| Sunburst Switchgrass | 2.3 | cde |
| Sunburst Switchgrass + Sunnyview Big Bluestem | 2.1 | de |
| Dakota Switchgrass | 1.3 | e |
| LSD 0.05 | 1.03 | |

2007 yields on the dryland plots at CGREC. All yields at each location followed by the same letter are not significantly different at the .05 level.

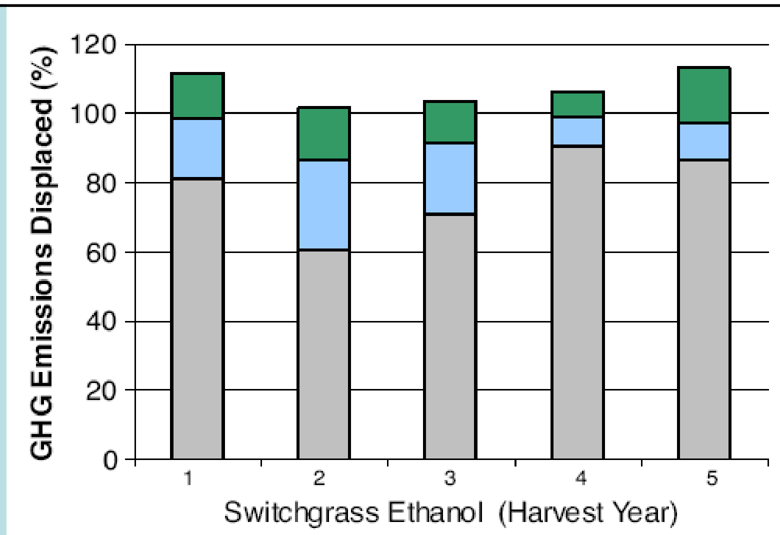
| Site Species | YieldT/AC | |
|---|---|---|
| CRP Mix (Intermediate & Tall Wheatgrass) | 3.4 | a |
| Alkar Tall Wheatgrass | 3.3 | a |
| Haymaker Intermediate Wheatgrass | 2.7 | b |
| CRP Mix (Wheatgrasses +alfalfa+Swt.clover) | 2.6 | b |
| Trailblazer Switchgrass | 1.9 | c |
| Sunburst Switchgrass | 1.8 | c |
| Sunburst Switchgrass + Mustang Alti wildrye | 1.6 | c |
| Sunburst Switchgrass + Sunnyview Big Bluestem | 1.6 | c |
| Magnar Basin + Mustang Alti wildrye | 1.5 | c |
| LSD 0.05 | 0.51 | |

2007 yields on the Irrigated plots at Williston. All yields at each location followed by the same letter are not significantly different at the .05 level.

| Site Species | YieldT/AC | |
|---|---|---|
| Sunburst Switchgrass + Mustang Alti wildrye | 6.4 | a |
| Sunburst Switchgrass | 5.8 | ab |
| Sunburst Switchgrass + Tall Wheatgrass | 5.7 | ab |
| Alkar Tall Wheatgrass | 5.0 | bc |
| Sunburst Switchgrass + Sunnyview Big Bluestem | 5.0 | bc |
| CRP Mix (Intermediate & Tall Wheatgrass) | 4.5 | cd |
| Dakota Switchgrass | 4.3 | cd |
| Haymaker Intermediate Wheatgrass | 4.1 | cd |
| Magnar Basin + Mustang Alti wildrye | 4.0 | d |
| CRP Mix (Wheatgrasses +alfalfa+Swt.clover) | 3.9 | d |
| LSD -0.05 | 0.92 | |

# How Much Energy is Saved if Cellulosic Biomass is used for Ethanol

- A study started at the Central Grasslands and other sites across the Northern Great Plains in 2001 evaluated switchgrass for biofuels for that for every unit of energy in there was 5.4 units of energy out.




**Estimated displacement (%) of GHG emissions by replacing conventional gasoline (baseline) with cellulosic ethanol derived from switchgrass.** Schmer, M. R., Vogel, K. P., Mitchell, R. B. & Perrin, R. K. “Net energy of cellulosic ethanol from switchgrass “Proc Natl. Acad. Sci. USA 105, 464-469 (2008)


? ? ? ?

?Questions?

# Crop Residues

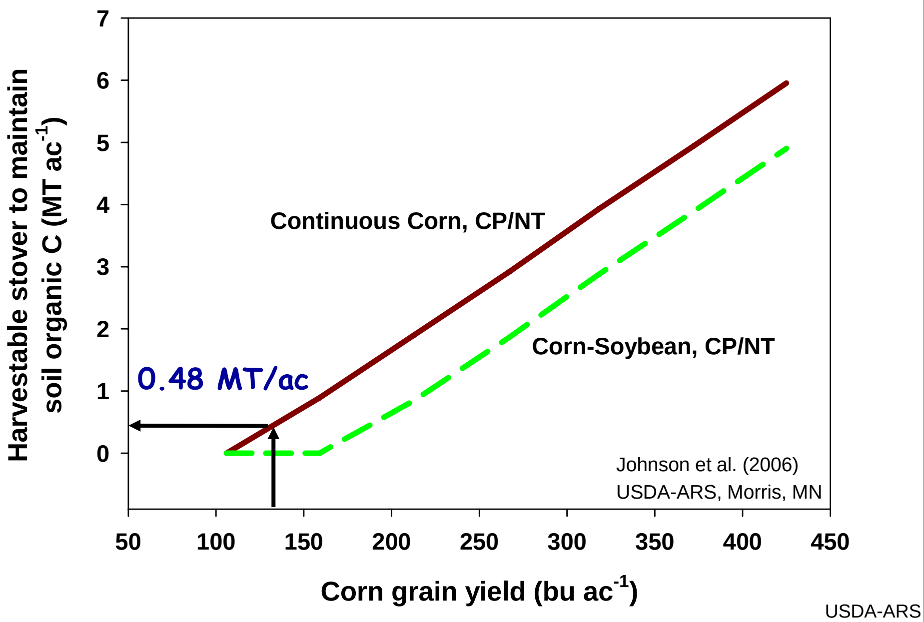
**Benefits:**

- Does not require change in land use.
- Relatively low-cost feedstock.

**Drawbacks:**

- Residue removal can negatively affect soil quality, and therefore, long-term viability of cropland. (Wilhelm et al., 2007)

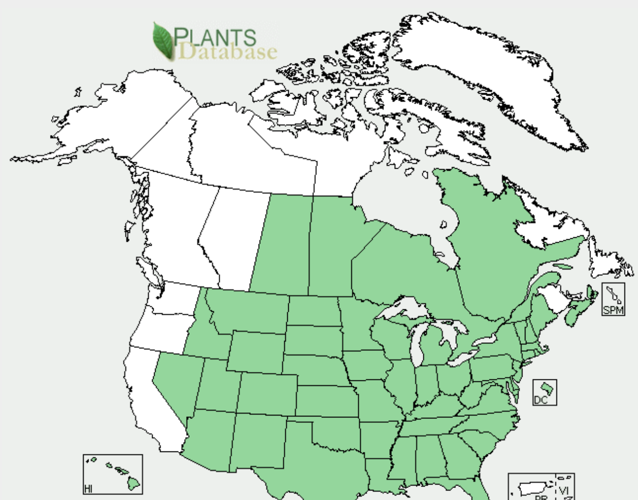
## Harvestable Corn Stover



## Where does that leave us?

### Herbaceous Crops as Biofeedstocks

- Switchgrass (*Panicum virgatum* L.)
  - Warm-season tallgrass species
  - Highly productive
  - Requires fewer inputs than annual crops
  - High Net Energy Yield (Schmer et al., 2008)
  - Suitable for planting on marginal land
  - Adapted to multiple ecoregions




USDA, NRCS. 2008. The PLANTS Database (http://plants.usda.gov, 19 January 2008). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

# Agronomic Performance:
## Biomass Productivity of Switchgrass

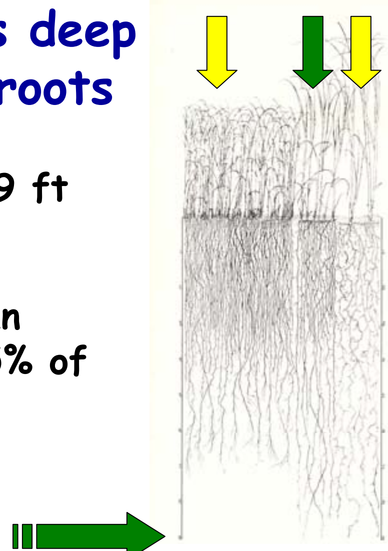
- Evaluated yield, phenology, and survival of eight cultivars in western ND.
- Key findings:
  - Sunburst was top yielding entry (1.3 – 5.1 MT/ac).
  - Greater biomass yield with harvest in September (2.4 MT/ac) than August (2.2 MT/ac).
  - Yield closely associated with water availability.

Berdahl, J.D., A.B. Frank, J.M. Krupinsky, P.M. Carr, J.D. Hanson, and H.A. Johnson. 2005. Biomass yield, phenology, and survival of diverse switchgrass cultivars and experimental strains in western North Dakota. Agron. J. 97:549-555.

USDA-ARS

# Switchgrass has deep and extensive roots

- Roots extend >9 ft into soil.
- Root biomass can account for >75% of total biomass. (Frank et al., 2004)



Weaver, 1965

## Switchgrass is considered to be an effective crop to sequester soil organic carbon

✓ How much, and at what rate, does soil carbon increase?

✓ At what depth(s) is carbon sequestered?

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## Evaluations to address questions

1. Evaluate soil carbon within established switchgrass stands and cropland on farms in Minnesota, North Dakota, and South Dakota.
2. Evaluate changes in soil carbon under switchgrass over five years on farms in North Dakota, South Dakota, and Nebraska.

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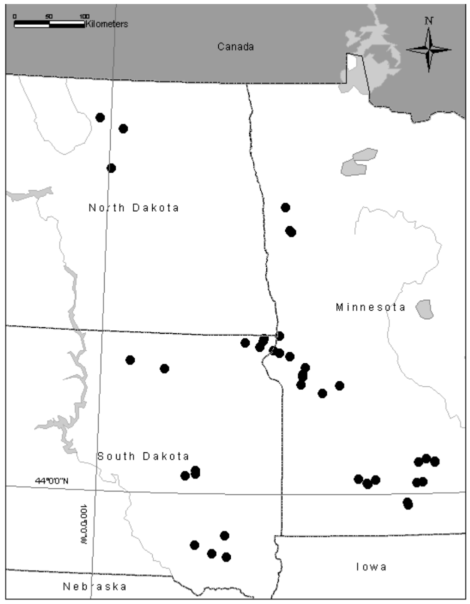
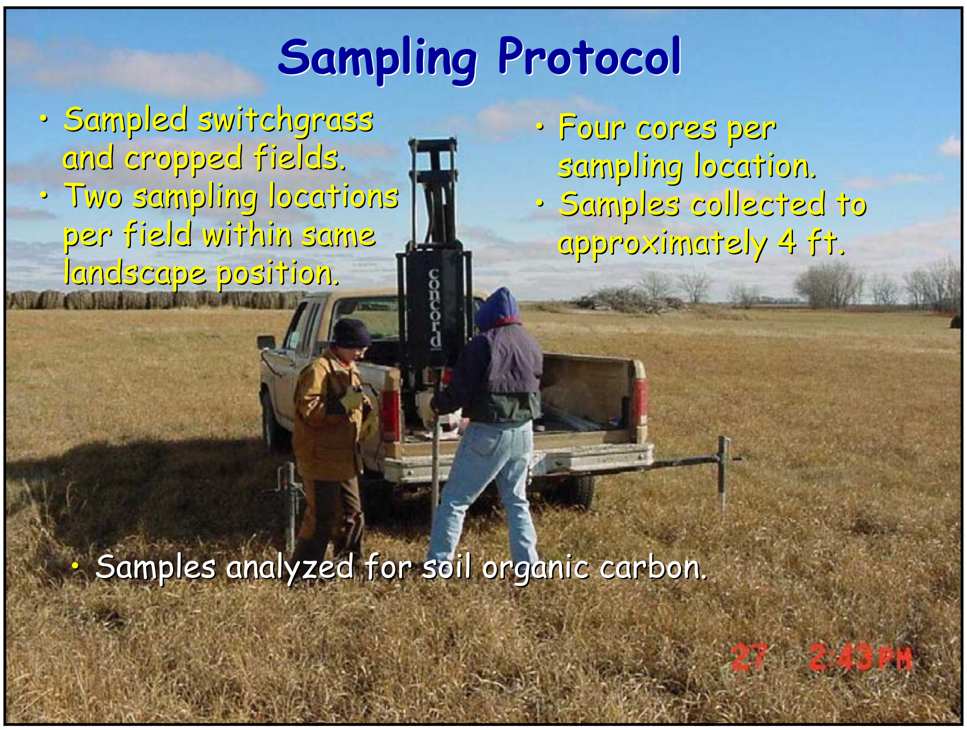
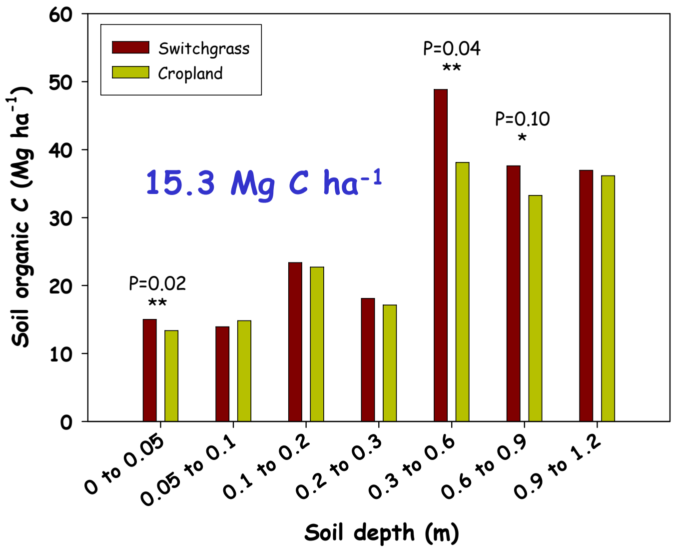
## First Evaluation

- ✓ **42 sampling sites**
- ✓ **Major Land Resource Areas:**
  53B
  55A,B,C
  56
  102A,B
  103
- ✓ **75 million acres**



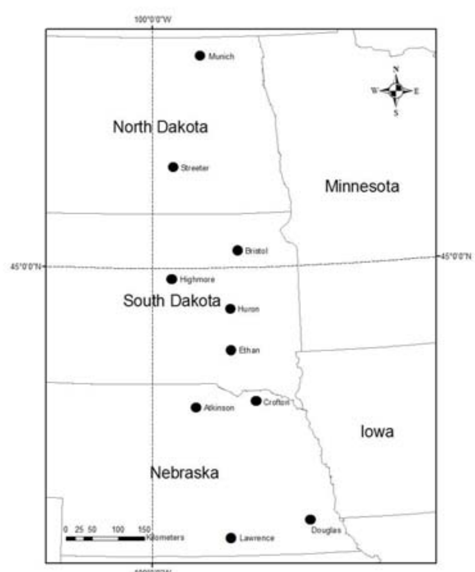



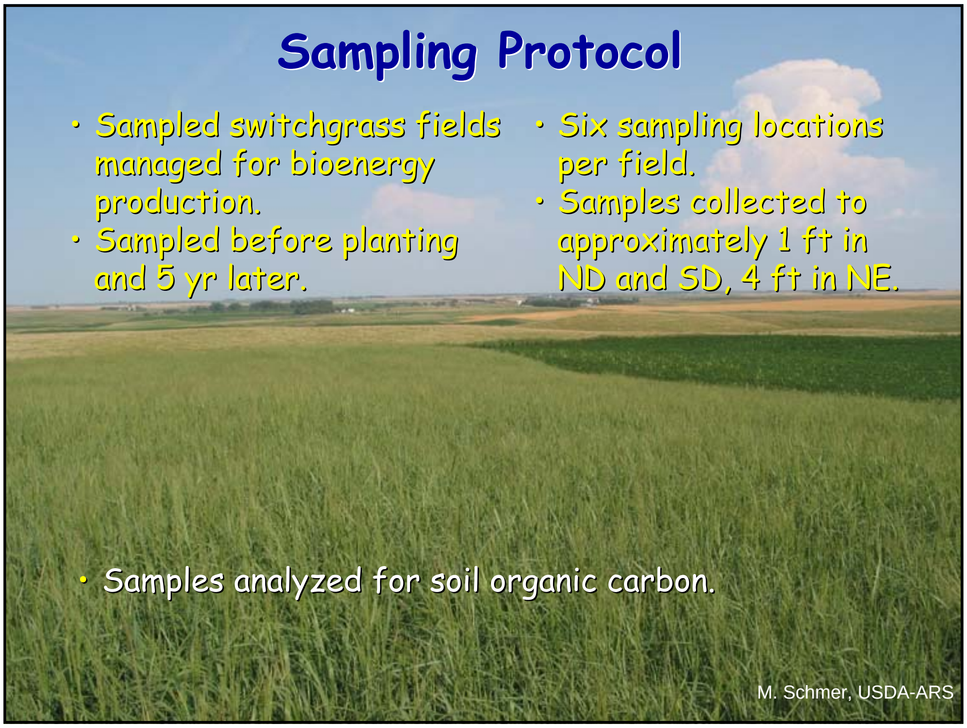


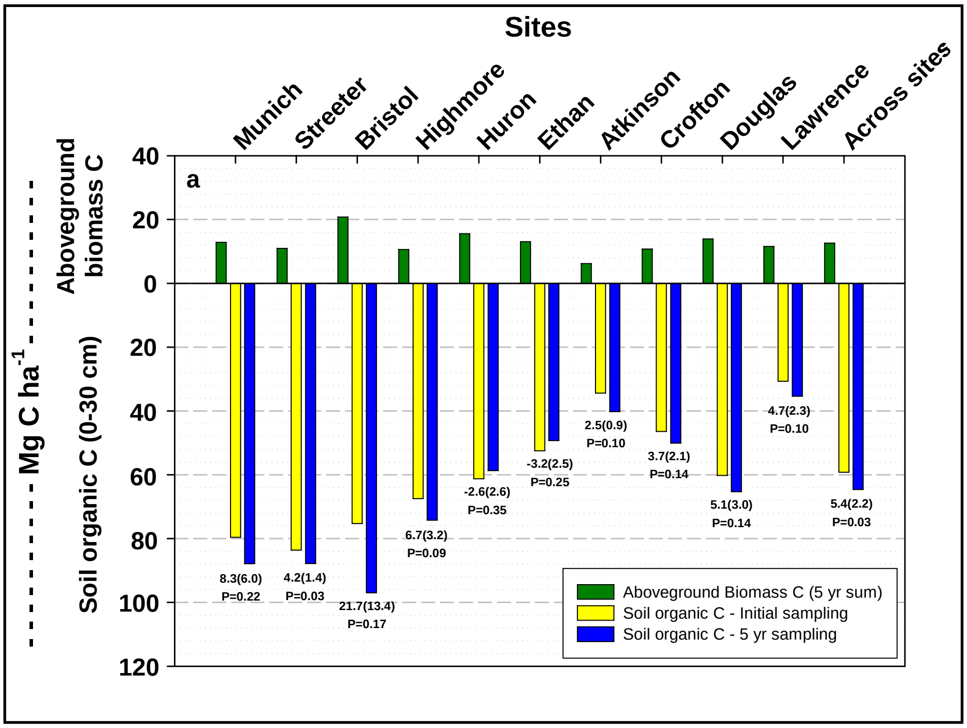

Liebig et al. (2005)

# Second Evaluation

- ✓ 10 sampling sites
- ✓ Major Land Resource Areas:
  - 53B, C
  - 55A,B,C
  - 65
  - 75
  - 102C
  - 106
- ✓ 75 million acres

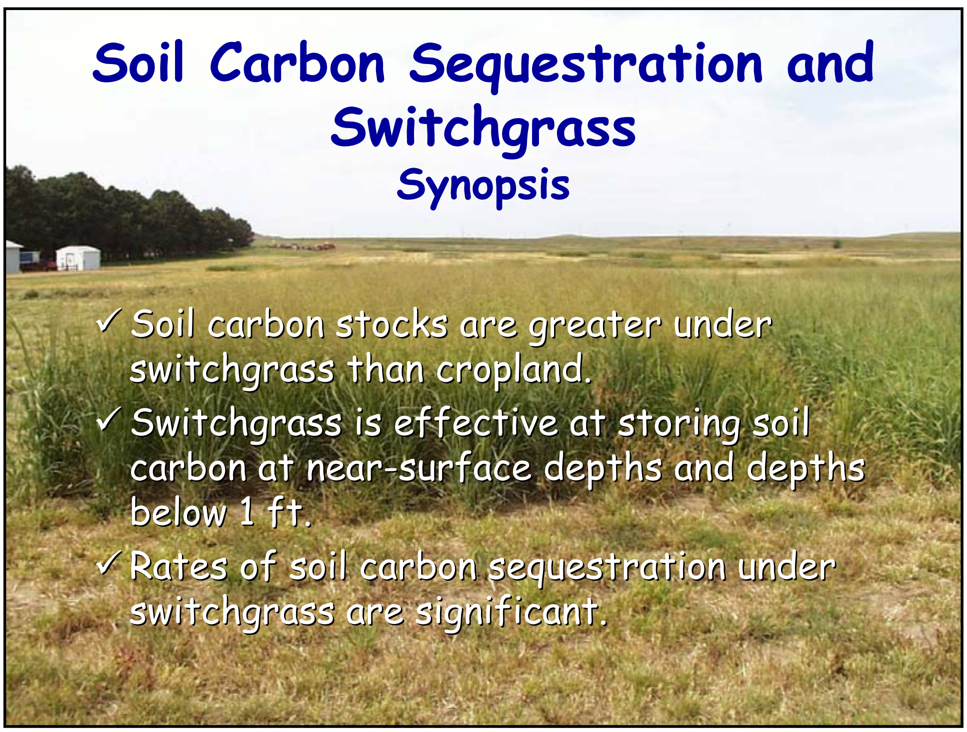



Sampling Protocol
• Sampled switchgrass fields managed for bioenergy production.
• Sampled before planting and 5 yr later.
• Six sampling locations per field.
• Samples collected to approximately 1 ft in ND and SD, 4 ft in NE.
• Samples analyzed for soil organic carbon.
M. Schmer, USDA-ARS


Sites
Munich
Streeter
Bristol
Highmore
Huron
Ethan
Atkinson
Crofton
Douglas
Lawrence
Across sites
a
Mg C ha-1
Aboveground biomass C
Soil organic C (0-30 cm)
40
20
0
20
40
60
80
100
120
8.3(6.0) P=0.22
4.2(1.4) P=0.03
21.7(13.4) P=0.17
6.7(3.2) P=0.09
-2.6(2.6) P=0.35
-3.2(2.5) P=0.25
2.5(0.9) P=0.10
3.7(2.1) P=0.14
5.1(3.0) P=0.14
4.7(2.3) P=0.10
5.4(2.2) P=0.03
Aboveground Biomass C (5 yr sum)
Soil organic C - Initial sampling
Soil organic C - 5 yr sampling

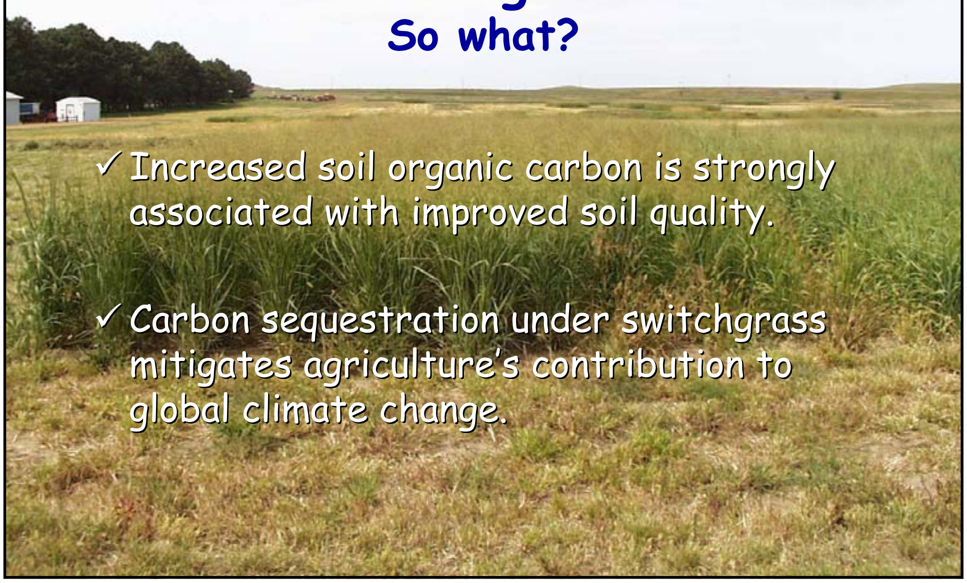
| | | | Mg C ha$^{-1}$ | | |
|---|---|---|---|---|---|
| Site | Depth (cm) | P-value | '00/'01 | '05/'06 | $\Delta$ yr$^{-1}$ |
| Munich, ND | 0-30 | 0.22 | 79.6 | 87.9 | 1.7 |
| Streeter, ND | 0-30 | 0.03 | 83.6 | 87.8 | 0.8 |
| Bristol, SD | 0-30 | 0.17 | 75.3 | 97.0 | 4.3 |
| Highmore, SD | 0-30 | 0.09 | 67.5 | 74.2 | 1.3 |
| Huron, SD | 0-30 | 0.35 | 61.3 | 58.7 | -0.5 |
| Ethan, SD | 0-30 | 0.25 | 52.5 | 49.3 | -0.6 |
| Atkinson, NE | 0-30 | 0.10 | 34.4 | 40.2 | 1.2 |
| Crofton, NE | 0-30 | 0.14 | 46.4 | 50.1 | 0.7 |
| | 0-120 | 0.60 | 120.3 | 126.7 | 1.3 |
| Douglas, NE | 0-30 | 0.14 | 60.2 | 65.3 | 1.0 |
| | 0-120 | 0.14 | 115.6 | 134.0 | 3.7 |
| Lawrence, NE | 0-30 | 0.10 | 30.7 | 35.4 | 0.9 |
| | 0-120 | 0.01 | 56.5 | 75.3 | 3.8 |
| **Across sites** | **0-30** | **0.03** | **59.2** | **64.6** | **1.1** |
| | **0-120** | **0.07** | **97.5** | **112.0** | **2.9** |

Liebig et al. (2007)



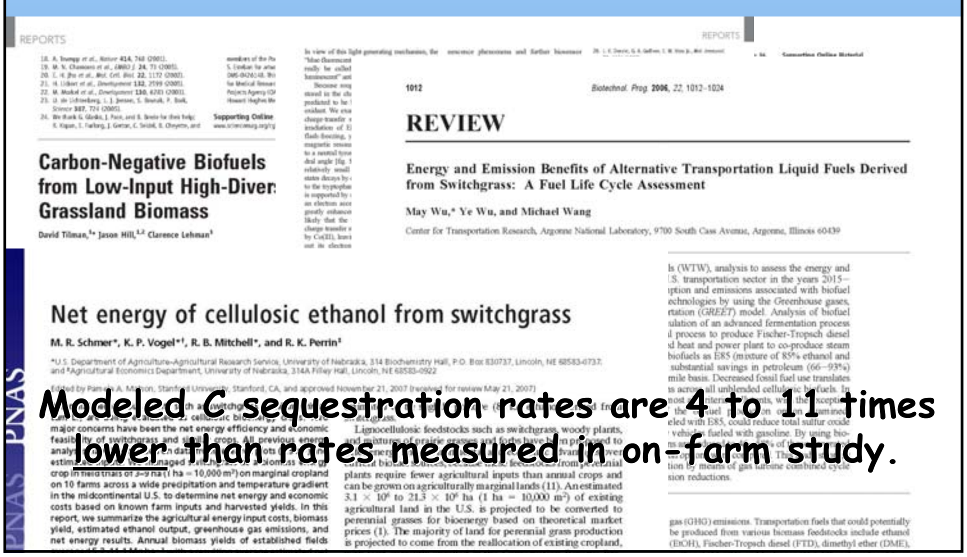
# Soil Carbon Sequestration and Switchgrass

### So what?



- ✓ Increased soil organic carbon is strongly associated with improved soil quality.
- ✓ Carbon sequestration under switchgrass mitigates agriculture's contribution to global climate change.

# Life-cycle Assessments: Net Greenhouse Gas Benefit



REPORTS

Carbon-Negative Biofuels from Low-Input High-Diver Grassland Biomass

David Tilman, Jason Hill, Clarence Lehman

1012 Biotechnol. Prog. 2006, 22, 1012–1024

REVIEW

Energy and Emission Benefits of Alternative Transportation Liquid Fuels Derived from Switchgrass: A Fuel Life Cycle Assessment

May Wu, Ye Wu, and Michael Wang

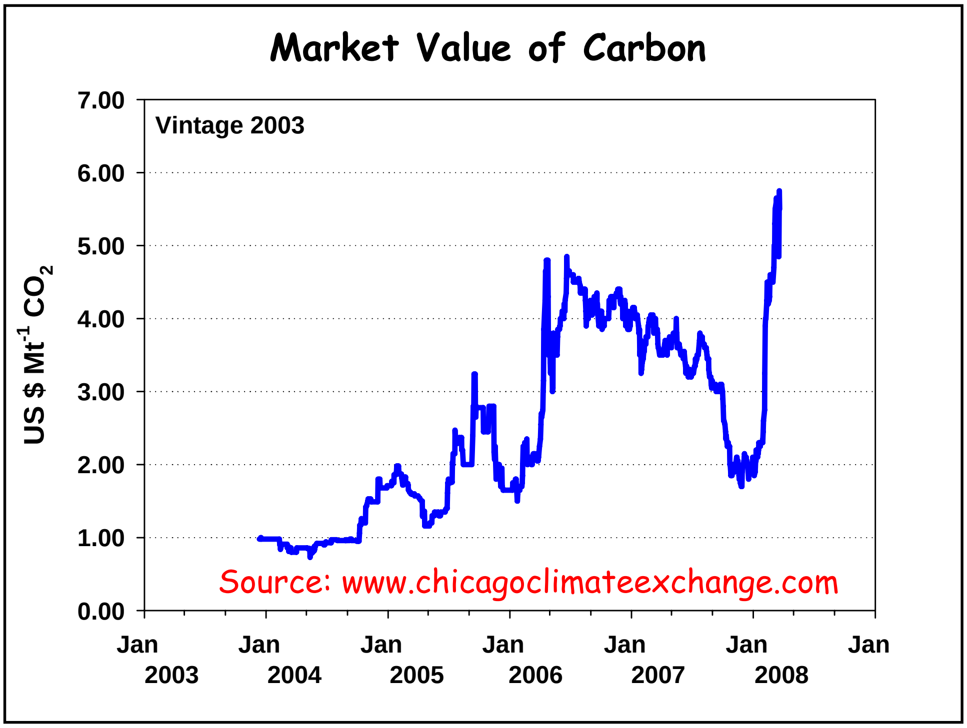
Center for Transportation Research, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

PNAS

Net energy of cellulosic ethanol from switchgrass

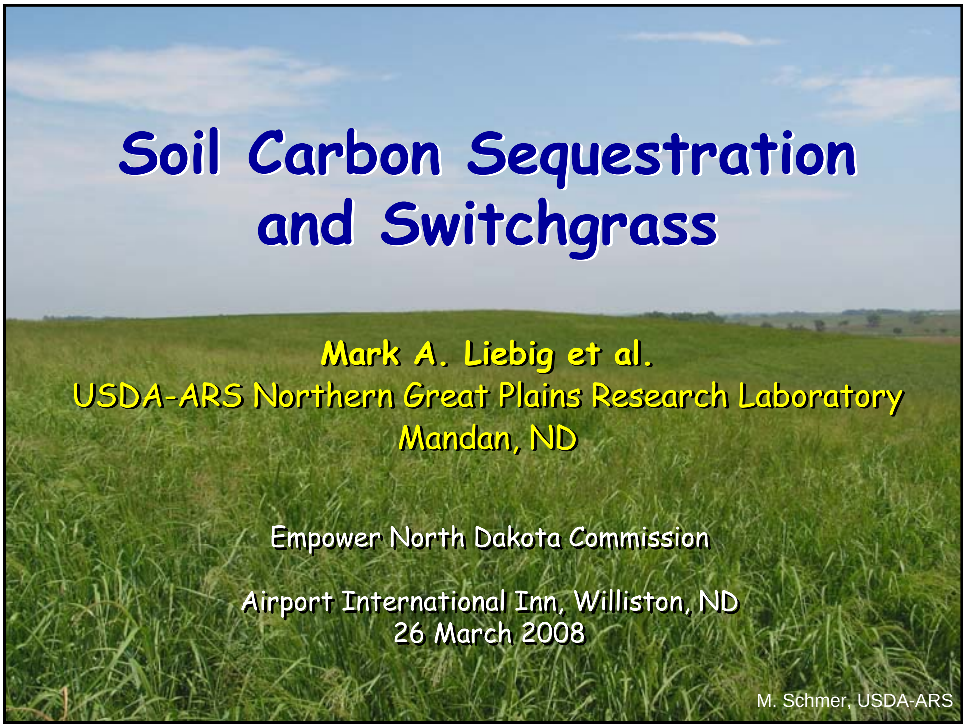
M. R. Schmer, K. P. Vogel, R. B. Mitchell, and R. K. Perrin

**Modeled C sequestration rates are 4 to 11 times <u>lower</u> than rates measured in on-farm study.**



Market Value of Carbon
Vintage 2003
US $ Mt-1 CO2
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Source: www.chicagoclimateexchange.com
Jan 2003
Jan 2004
Jan 2005
Jan 2006
Jan 2007
Jan 2008
Jan


Thank You
Northern Great Plains Research Laboratory
USDA-ARS, Mandan, ND
http://www.mandan.ars.usda.gov/
M. Schmer, USDA-ARS




# Bioenergy as an Alternative to Fossil Fuels

USDA-ARS

# "Biomass CHP" Plant Economics

Overview of a MN wood fired CHP project opportunity considered by GRE

2007 Data

GREAT RIVER ENERGY®

## Overview

- "Minnesota Energy"
  - Need, opportunity, benefits
  - High level overview … project
- Project economics
  - Variables Used
  - Wood demand vs. supply
  - 35 MW plant results - +/- 35%
- Financing options explored
- GRE perspective on Biomass CHP

GREAT RIVER ENERGY®

# Benefits & Risks

- Participant Benefits
  - Provides economical energy to steam host, generate renewable electricity, stimulates economic development in the local town
- Project Benefits
  - Take advantage of available wood supply in region
  - Provide support to regional transmission grid
  - Strengthen relationship with a large customer
- Risks
  - Securing LT supply contracts, Variables with wood market
  - Competition for wood – biomass plants in Northern Minnesota- Hibbing 25 MW, Virginia 25 MW, White Lakes 50 MW (proposed), Bemidji 14 MW

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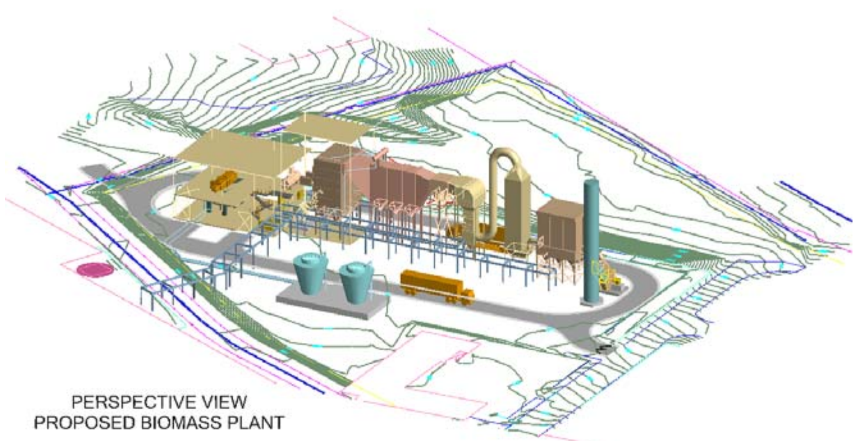
# Plant Conceptual Layout



PERSPECTIVE VIEW
PROPOSED BIOMASS PLANT

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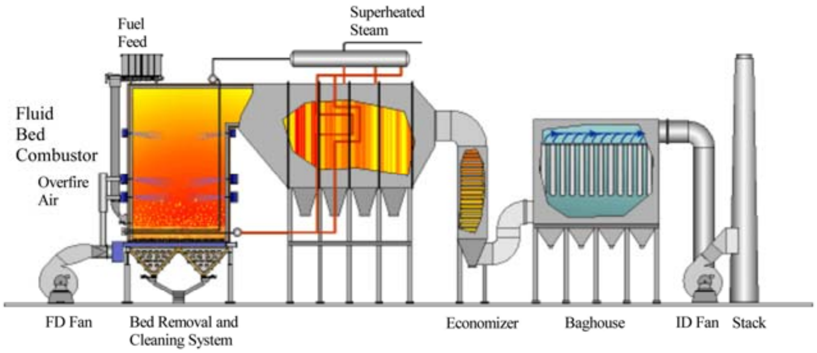
# Process View

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# Plant Indicative Economics

| Plant Size | Cost | MW Output | GRE $/MWhr | GRE 30 yr Avg | Steam Host $/mmbtu | Steam Host 30 yr Avg |
|---|---|---|---|---|---|---|
| 25 MW | $129,660,000 | 13.4 | $ 120.00 – 125.00 | $ 80.00 – 90.00 | $ 9.00 – 10.00 | $ 7.00 – 8.00 |
| 35 MW | $162,811,159 | 23.4 | $ 110.00 – 115.00 | $ 80.00 – 85.00 | $ 9.00 – 10.00 | $ 7.00 – 8.00 |
| 45 MW | $185,500,000 | 34.2 | $ 95.00 – 100.00 | $ 70.00 – 75.00 | $ 9.00 – 10.00 | $ 7.00 – 8.00 |

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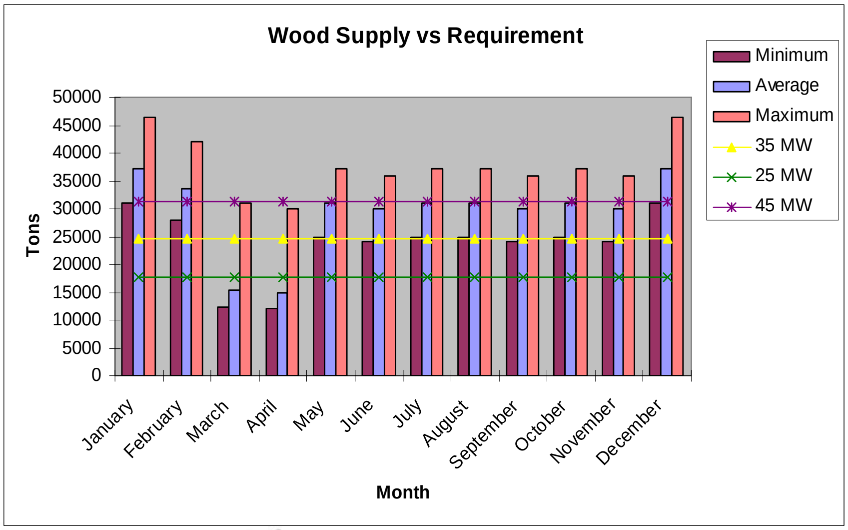
# Wood Analysis

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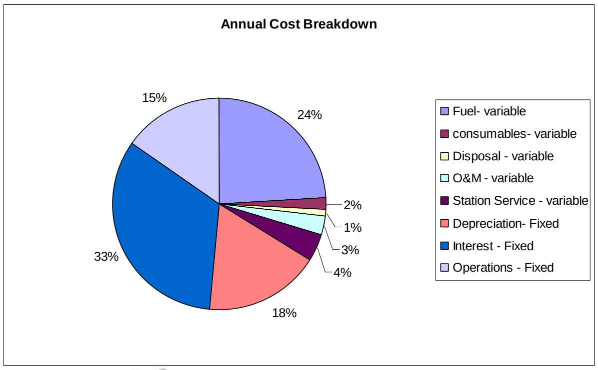
# 35 MW Plant Economics

| 35 MW | Cost | GRE $/MWhr | GRE 30 yr Avg | Steam Host $/mmbtu | Steam Host 30 yr Avg |
|---|---|---|---|---|---|
| - | $ 162,811,159 | $ 110 – 115 | $ 80 – 85 | $ 9 – 10 | $ 7 – 8 |
| + 35% | $202,076,898 | $ 125 – 130 | $ 90 – 95 | $ 11 – 12 | $ 8 – 9 |
| - 35% | $126,067,875 | $ 80 – 85 | $ 65 – 70 | $ 8 – 9 | $ 6 – 7 |

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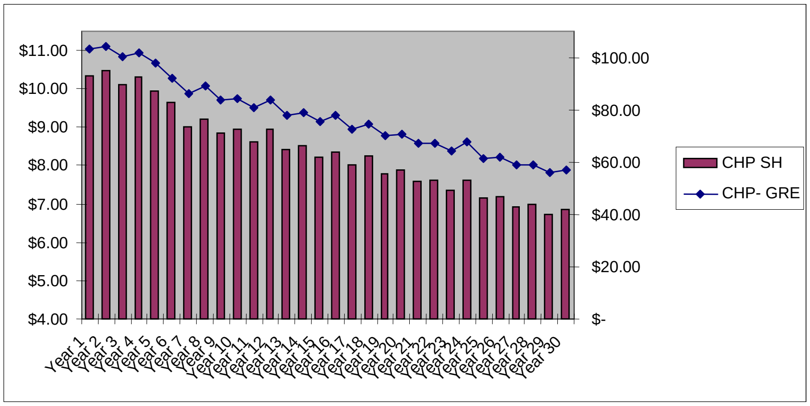
# 30 year baseline economics

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# Financing options considered

- Clean Renewable Energy Bonds
  - 0% interest on amount financed - $50 million
- New Market Tax Exempt Bonds
  - Interest only payments for first 7 yrs. -- $20 million
- Tax Exempt Solid Waste Bonds
  - 2% discount to Long Term Rate -- $4 million

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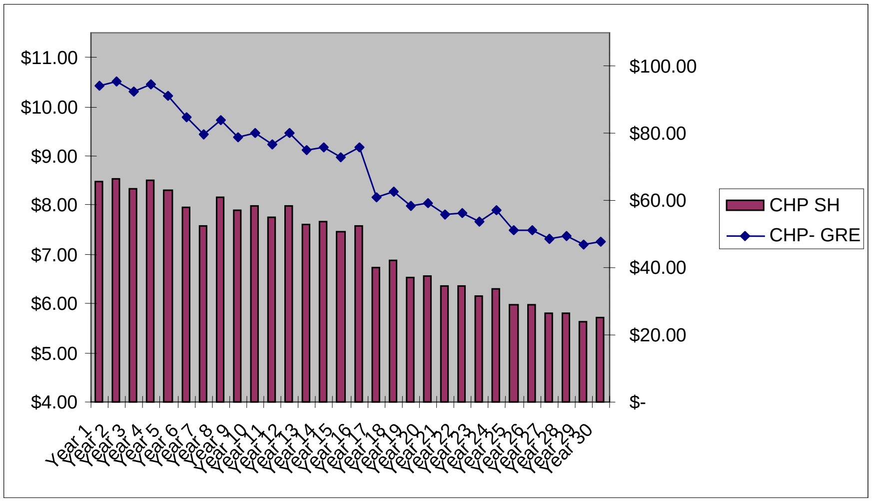
## Financing assistance does help

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## GRE perspective on *Biomass CHP*

- Biomass "pros"
  - $CO_2$ neutral
  - Baseload in small size
  - Economic development in rural areas
  - CHP significantly improves thermal efficiency
- Challenges
  - High capital relative to other options
  - Securing a "guaranteed" cost competitive fuel supply
- Current project status
  - More expensive than other generation options
  - Decision not to proceed
  - However … we remain interested and open to project opportunities

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APPENDIX I

# BIOMASS INDUSTRY SWOT

<table>
<tr><th><u>STRENGTHS</u></th><th><u>WEAKNESS</u></th></tr>
<tr><td>•Public perception that Biomass is good for economic development and for industries<br>•Land available in ND – marginal land suitable for Biomass<br>•Political climate friendly toward development of energy projects<br>•Climate and soil suitable for some energy crops (i.e. Perennial grasses) Oak Ridge National Lab study identified ND with the greatest potential for switch grass and other dedicated energy crops. Native species of biomass are more resistant to pests and diseases. (Assumptions made for the study may change with time.)<br>•Excellent research base for new technologies in converting biomass to energy and fuels. Public and private funding directed toward research, development and demonstration projects.<br>•State and Federal Incentives: Green Power programs, carbon neutral or renewable fuel premiums, utilize national notoriety in leading production of commodities, $5M appropriation from Renewable Energy Office (funds can be used for innovative biomass projects), Energy bill mandates for 21 billion gallons of cellulosic-based ethanol by 2022.<br>•ND leads the nation in crop production experience in 14 different commodities, offering huge potential for production of energy crops.<br>•Beneficial to rural communities for economic development/job opportunities.<br>•Friendly regulatory environment.</td><td>•Not currently cost-competitive with other alternatives such as lower priced fossil fuels<br>•Infrastructure challenges such as lack of transmission for electrical production, lack of pipelines for liquid fuels, lack of roads and year-round facilities for hauling and storage of low-density biomass to reach remote markets.<br>•Climatic and Geographic limitations: short growing season, dry climate, and inhospitable climate for trees in some areas, need to use marginal lands, premium lands needed for higher return food crops.<br>•Lack of market – supply side and transparent pricing.<br>•Technological breakthroughs required before biomass for fuel industry becomes reality.<br>•State and federal incentives limited at this time and the appropriations from the Renewable Energy Office require a cash match, which limits funding to those projects that industry will financially support. University or other public research necessary to develop technology may not be funded by industry.</td></tr>
<tr><th><u>OPPORTUNITIES</u></th><th><u>THREATS</u></th></tr>
<tr><td>•CRP land could be converted to biomass production<br>•Co-firing opportunities could improve economics<br>•Meets RFS needs for region<br>•ND suitable for switch grass production<br>•Bio fuels from Cellulose<br>•Growing demand regionally and nationally for power and fuel<br>•Carbon markets<br>•Wildlife habitat<br>•Support of conservation groups<br>•Federal and state funding available for studying concepts or developing market<br>•Development of industry will create significant opportunities for new and expanding businesses, jobs, rural development, children in rural schools and expanded tax base<br>•New perennial crop systems that can enhance soil while producing biomass</td><td>•Economics not able to support the infrastructure needed<br>•Food verses fuel perception (food prices driven more by energy cost)<br>•Venture capital may not be available when technology becomes economically viable<br>•North Dakota’s proximity to markets<br>•North Dakota’s broad array of other renewable and non-renewable energy resources</td></tr>
</table>